Appendix A

1. Introduction

This chapter provides a brief description of the Denny Way/Lake Union CSO Control Project history, summarizes the Black & Veatch scope of work and presents the design report organization.

1.1. Project History

In January 1987, the Washington State Department of Ecology (Ecology) published a new regulation on CSO control (WAC 173-245-020(22)) defining the "greatest reasonable reduction" of CSOs as "control of each CSO such that an average of one untreated discharge may occur per year." The regulation further required that, by 1988, each community must submit a CSO-reduction plan specifying the means of complying with the new CSO control mandate. Metro's *1988 Combined Sewer Overflow Control Plan* (the *1988 Plan*) pledged a continuing effort to achieve the long-term goal of one untreated discharge per outfall per year. Recognizing that reducing CSO discharges to one untreated discharge per year at Denny Way and other locations would take time, Metro worked with Ecology to develop an interim goal of a 75 percent CSO volume reduction system-wide (including 50 percent volume reduction at Denny Way) by the end of the year 2005.

Subsequent to the *1988 Plan*, Ecology has agreed to waive the 75 percent volume reduction requirement imposed in 1988 in favor of an approach to scheduling CSO control projects based on quantity of human use and potential pathogenic health risk. Ecology's agreement to waive the 75 percent volume reduction requirement was based, in part, on its recognition of King County's efforts to fully control Denny Way overflows by 2006.

The same Ecology CSO-control mandate that applies to the County applies to the City of Seattle (City). In 1992, the City recognized the hydraulic link between the two systems and proposed working together with Metro to find a joint, basin-wide solution to the overflow problems. The result is the Denny Way/Lake Union CSO Control Project.

The *1988 Plan* called for a partial separation project to reduce overflows by 50 percent of baseline at the Denny Way regulator station. In 1992, Metro conducted a feasibility study to evaluate a joint City and County CSO control at Denny. The *1992 Feasibility Study* concluded that a joint storage and CSO treatment might be a more promising and cost-effective approach to overflow reductions for Lake Union and Denny. *The Denny Regulator Accelerated CSO Control Program Report (1995 Denny Report)* reexamined control options including partial separation, storage, on-site CSO treatment facilities, and conveyance to existing facilities for treatment as a way to achieve control of overflows. The *1995 Denny Report* evaluated various combinations of these approaches with the intent of arriving at a preferred CSO control project for the Denny basin.

The *1995 Denny Report* recommended a preferred alternative for controlling overflows at the Denny Way regulator station consisting of the following components: 6,800 feet of 18-foot finished inside diameter 12.9 million gallon CSO storage tunnel; piping and regulator construction to connect the east end of the new tunnel with the existing Lake Union tunnel to accept flows from the City system; a 2.5 million gallon concrete storage tank located on the west side of Elliott Avenue West; 150-foot long, 96-

inch diameter extension to the existing Denny CSO outfall; and a 1,600-foot long, 60-inch diameter outfall for discharge of flows in excess of the storage capacity.

In May 1997, the King County *Denny Way/Lake Union CSO Control Facilities Plan (1997 Facilities Plan)*, defined the County related project elements including system hydraulics; tunnel and pipeline alignments; and outfall, conveyance, and storage capacities. The *1997 Facilities Plan* also prepared construction cost estimates and a construction schedule. Preliminary scheduling work indicated that construction of the first project element would be completed in year 2003.

In the spring of 1997, King County divided their portion of the Denny Way/Lake Union CSO Control Project into three separate engineering design contracts and selected separate engineering consultants for each contract. Black & Veatch was selected for Contract A which consists of CSO storage and treatment facilities including the Elliott West CSO Control Facility, Mercer Street Tunnel and Marine Outfalls.

1.2. Scope of Work

Black & Veatch will perform preliminary design, final design, and engineering support services during construction for the Mercer Street Tunnel, Elliott West CSO Control Facility, and Marine Outfalls (Contract A). Cosmopolitan Engineering Group is responsible for the design engineering for the South Lake Union CSO, Central Trunk CSO, and the Lake Union Tunnel Regulator. Rosewater Engineering will perform design engineering services for the Effluent and CSO pipelines and associated structures. King County is responsible for program management with the assistance of a Program Management Consultant.

The Black & Veatch scope of work for the preliminary design phase included the following major work tasks:

- Perform project wide geotechnical investigations, surveying and mapping, odor control evaluation, hydraulic analysis, and instrumentation and control strategy for all three design contracts.
- Perform preliminary engineering to approximately the 30 percent final design completion level for the Elliott West CSO Control Facility, Mercer Street Tunnel, and the Marine Outfalls.
- Prepare a design report and preliminary design drawings summarizing the preliminary engineering phase work for Contract A.
- Prepare draft geotechnical data reports for all three contracts.
- Prepare final design base mapping for all three contracts.

1.3. Design Report Organization

This Design Report has been prepared in two separate volumes. The content of each volume is described below.

Volume 1. Design Report

This volume summarizes the preliminary engineering work performed for Contract A and is organized into three parts.

- Part A - Design Report
- Part B - Outline Specifications
- Part C - Technical Memoranda

Volume 2. Preliminary Design Drawings

This volume presents the Contract A preliminary design drawings for the Elliott West CSO Control Facility, Mercer Street Tunnel, and Outfalls (Elliott West Outfall and Denny Way CSO Outfall Extension).

2. Project Description and Costs

This chapter provides a brief description of the overall Denny Way/Lake Union CSO Control Project, describes King County's planned combined sewer overflow (CSO) control facilities for Contract A, and presents preliminary project costs.

2.1. Overall Project Description

The Denny Way/Lake Union CSO Control Project is a joint undertaking of the City of Seattle (City) and King County (County). The joint project was originally divided into four phases, including a CSO volume reduction phase (Phase 3) and a CSO treatment phase (Phase 4). Subsequently, King County abandoned the Phase 3 project in favor of a CSO treatment project that will provide storage, solids reduction, and disinfection at a lower total cost than separate Phase 3 and Phase 4 projects.

2.1.1. City of Seattle's CSO Control Projects

The City of Seattle will construct two separate projects as part of the overall Denny Way/Lake Union CSO Control Project. The first project of the joint Denny Way/Lake Union CSO Control Project is the City of Seattle's Phase 1 project to increase the capacity of the City's existing combined sewers along the east and south sides of Lake Union. Phase 1 will eliminate two City combined sewer overflows through the installation of four flow-control structures and over two miles of pipe, ranging in size from 18-inch to 60-inch diameter. Construction of the Phase 1 improvements began in March 1996 and was completed in late 1997. The new, larger Phase 1 conveyance system will carry more water, but until Phase 2 and the County CSO control projects are complete, the flows collected in Phase 1 must continue to be discharged into Lake Union.

The second City of Seattle project will complete the City's conveyance system upgrade, eliminate one more Lake Union overflow outfall, and link the expanded conveyance system with the storage constructed as part of King County's CSO control project. Phase 2 project elements are expected to include approximately 1,150 feet of 60-inch diameter pipe, approximately 1,800 feet of 18-inch to 24-inch pipe, and the necessary facilities to connect the Phases 1 and 2 improvements to the County improvements. Completion of Phase 2 would coincide with the completion of King County's control project, and the City would begin to realize the CSO-control benefits from both Phase 1 and Phase 2 immediately upon completion of Phase 2 and the County project. Following completion of Phase 2, all City overflows along the east and south side of Lake Union would comply with Ecology's one untreated overflow event per outfall per year limitation.

2.1.2. King County's CSO Control Project

The County's Denny Way/Lake Union CSO Control Project consists of facilities that will accommodate the increased City Lake Union flows from the City of Seattle, will reduce the Dexter CSO discharge to one untreated discharge per year, and will reduce discharges at the Denny regulator station to a minimum of 50 percent of the baseline CSO annual volume (405 millions gallons).

King County has divided their portion of the Denny Way/Lake Union CSO Control Project into three separate engineering design contracts:

Contract A: CSO storage and treatment facilities including the Elliott West CSO Control Facility, Mercer Street Tunnel and Marine Outfalls.

Contract B: South Lake Union CSO control facilities including the Lake Union Tunnel Regulator and Pipeline, South Lake Union CSO Pipeline and Manhole, and Central Trunk Diversion Structure and Pipeline.

Contract C: Denny Area CSO control facilities including the Elliott Bay Interceptor Control Structure, Elliott West CSO Pipeline, Denny Diversion Structure, System Drain, and Elliott West Effluent Pipeline.

2.2. Contract A Description

The preferred project configuration selected by King County and presented in the draft facilities plan entitled *Denny Way/Lake Union CSO Control Facilities Plan, Preliminary Draft Report, May 1997,* was the starting configuration for the design. Contract A configuration was refined during the 30 percent design engineering effort by revising the Mercer Street Tunnel alignment at the easterly end and deepening the Elliott West CSO Control Facility Pump Station to allow the Pump Station to function as an effluent Pump Station only. Other refinements included selecting CSO treatment and pumping equipment, finalizing the horizontal and vertical alignments for Mercer Street Tunnel and Marine Outfall, and developing the Elliott West CSO Control Facility Site layout.

Project elements of Contract A are shown on Figure 2-1 and are described in the following sections.

2.2.1. Elliott West CSO Control Facility

The Elliott West CSO Control Facility will include three major structures, as shown on Figure 2-2:

- Pump Station.
- CSO Treatment Structure.
- Chemical Storage and Odor Control Area.

2.2.1.1. Pump Station. The Pump Station structure will consist of two major components: Wetwell and Drywell. The Wetwell will receive flows from the Mercer Street Tunnel and from the EBI through the Elliott West CSO Pipeline. The Wetwell level will control the storage capacity of the tunnel.

The Drywell will have five levels including the pump, intermediate, motor, ground and mezzanine levels. The pump level will house six sewage pumps with space provided for a seventh future pump. Each pump will be provided with its own adjustable frequency drive unit and will have a capacity of 41.67 mgd. The intermediate level will house the pump shaft support and bearing housings. The motor level will contain the six pump motors of 400 horsepower each. The ground level will contain an Electrical Room, adjustable frequency drives, an overhead bridge crane for removal of the pumps and motors, janitor storage room, sampling room and lavatory. The mezzanine level will contain the heating and ventilation equipment Mechanical Room.

2.2.1.2. The CSO Treatment Structure The CSO Treatment Structure will provide floatable material removal and disinfection. Floatable material removal will be provided by vertical fixed screens located in the Pump Discharge Channel. After the storm event, the captured floatable material in the channel will be drained into the EBI for conveyance to the West Point Treatment Plant for disposal. The screened flow will discharge into the Effluent Channel where disinfection will occur. Flow measurement will be provided by use of magnetic flow meters in the pump discharge lines.

Disinfection of all flows discharged to the Elliott West Outfall will be provided using sodium hypochlorite. Induction mixers will mix the sodium hypochlorite into the flow in the Effluent Channel Mixing chamber prior to discharging to the Elliott West Effluent Pipeline. The Effluent Pipeline will provide approximately five minutes of chlorine contact time at 300 mgd.

Dechlorination will be accomplished through injecting sodium bisulfite into the Dechlorination Injection Structure upstream of the Elliott West Transition Structure. A sodium bisulfite feed line will be installed from the Denny Regulator to the Dechlorination Injection Structure.

2.2.2. Chemical Storage and Odor Control Area

The Chemical Storage and Odor Control Area consists of the following components:

- Chemical Storage Area.
- Odor Control Area.

2.2.2.1 Chemical Storage Area. The Chemical Storage Area will house the storage and feed equipment for sodium hypochlorite and sodium bisulfite. The sodium hypochlorite area will be covered, but not completely enclosed. The sodium bisulfite area will be totally enclosed. Concrete walls will be provided to contain chemical spills. A chemical feed station with valves and quick disconnect type fittings will be provided for filling the tanks.

2.2.2.2 Odor Control Area. The Elliott West CSO Control Facility has two separate areas that will require odor control: the Wetwell and the CSO Treatment Structure. The Wetwell will share a common headspace with the EBI control structure. During all flow conditions, except when the EBI is surcharged, odor emissions from the wastewater in the interceptor sewer will occur. To prevent corrosion of the structures, continuous odor control will be provided. The CSO Treatment Structure, which houses the Pump Discharge Channel screens and mixing chamber, will have high turbulence and emissions when in operation.

The Odor Control Area will house the two Phoenix™ Carbon Systems that will provide odor control for the Wetwell and CSO Treatment Structure. Each unit will provide 11,000 cfm of ventilation.

2.2.3. Mercer Street Tunnel

The Mercer Street Tunnel includes the following elements as shown on Figure 2-3:

- A 7.2 million gallon CSO storage tunnel extending beneath Mercer Street from Elliott Avenue West to near the intersection of Mercer Street and Dexter Street.
- A Mercer Street Tunnel Drop Structure at the East Tunnel Portal near the intersection of 8th Avenue and Roy Street, which would connect the tunnel with the Lake Union CSO, South Lake Union CSO, and Central Trunk CSO pipelines.
- A West Tunnel Portal located adjacent to the Elliott West CSO Control Facility Site.

2.2.3.1. Mercer Street Tunnel. The 6,200 foot long Tunnel alignment runs from the West Portal adjacent to the Elliott West CSO Control Facility Site, under Mercer Street from Elliott Avenue West to the Mercer Street Tunnel Drop Structure. The Tunnel will have an inside diameter of 14 feet 8 inches. The Tunnel invert elevation will be 83.0 (Metro Datum) at the Mercer Street Tunnel Drop Structure and 75.0 (Metro Datum) at the West Tunnel Portal. No permanent forced air ventilation or lighting is being considered for the tunnel.

The horizontal alignment of the Mercer Street Tunnel will proceed east under West Mercer and Mercer Streets until it approaches Dexter Street where it will curve north toward the Mercer Street Tunnel Drop Structure. The entire alignment is located within public right-of-way

2.2.3.2. West Tunnel Portal. At the west end of the Tunnel, the vertical alignment will be at invert elevation 75.0 (Metro Datum) to eliminate the Elliott Avenue undercrossing proposed in the Draft Facilities Plan. The vertical alignment revision will allow the West Tunnel Portal to be located on the Elliott West CSO Control Facility Site. The West Portal will be used for tunnel machine access to the Drop Structure. It will also be used as an access/egress point for workers and rail cars (to remove tunnel cuttings). The West Portal excavation will be adjacent to the excavation required for construction of the Elliott West CSO Control Facility.

2.2.3.3. Mercer Street Tunnel Drop Structure. The Mercer Street Tunnel Drop Structure will be an underground, concrete structure containing one spiral drop. The structure will have the following influent pipelines: Central Trunk CSO, South Lake Union CSO, and Lake Union CSO.

The Drop Structure will contain a permanent access shaft for maintenance access to the Tunnel. Access to the street above will be through a hatch and a concrete lift slab.

The structure will also contain an air shaft and odor control room. The recommended odor control method is a passive activated carbon system.

2.2.4. Marine Outfalls

The marine outfalls have the following components as shown on Figure 2-4:

- Dechlorination injection structure.
- Transition structure and onshore pipelines.
- Inshore outfall portion extending to 20 feet water depth (MLLW) for the Denny CSO Outfall Extension and the Elliott West Outfall.
- Offshore outfall portion extending from 20 feet to 60 feet depth (MLLW) for the Elliott West Outfall only.

2.2.4.1. Dechlorination Injection Structure. The dechlorination injection structure will be constructed upstream of the Elliott West outfall pipe for mixing sodium bisulfite into the treated discharge. The injection structure will receive sodium bisulfite through an approximately 2-inch diameter feed pipeline from the Denny Regulator. A diffuser and mixer will be used to mix the sodium bisulfite into the Elliott West Outfall pipe at the injection structure.

2.2.4.2. Transition Structure and Onshore Portion. The new transition structure will be installed south of the existing Denny Way discharge structure. The transition structure will be a reinforced concrete structure designed to be constructed from within a cofferdam. A flap gate on the Denny Way CSO Outfall Extension at the transition structure is proposed to prevent backflow into the EBI during high tide.

The transition structure will be required to blend into the local surroundings and to facilitate access for maintenance purposes. The top of the structure will be at a similar elevation as the existing park (approximately 16 feet above MLLW). The exposed top of the transition structure will be made less visible by the addition of landscaping and art work. The offshore edge of the structure will be protected by rip-rap.

The onshore outfall portion will include the new 96 inch diameter pipe from the Dechlorination Injection Structure to the Transition Structure, and the new 96-inch diameter pipe from the existing 96-inch diameter Denny outfall pipe to the Transition Structure.

2.2.4.3. Inshore Outfall Portion. The inshore outfall extends approximately 120 feet from the Transition Structure to a point where the water depth is approximately 15 feet (MLLW) and comprises the entire Denny Way CSO Outfall Extension and Discharge Structure, and a portion of the new Elliott West Outfall.

The Denny Way CSO Outfall Extension consists of approximately120 feet of 120-inch diameter pipe terminating in a discharge structure. The Denny Way discharge structure is to be located approximately 130 feet from the shoreline and will provide the means for discharging the Denny Way CSO flows into Elliott Bay. The structure will also serve as the take-off point for the offshore section of the 96-inch Elliott West Outfall, which is parallel to the Denny Way Extension and extends an additional 360 feet offshore

2.2.4.4. Offshore Outfall Portion. The offshore Elliott West Outfall extends approximately 360 feet further to a water depth of 60 feet below MLLW and comprises the remaining portion of the 96-inch diameter Elliott West Outfall. The Elliott West Outfall discharge structure will be located in about 60 feet of water, approximately 490 feet from the shoreline. It will discharge treated effluent intermittently, averaging about 8 to 10 times per year.

2.3. Budget Level Construction Cost Estimate

The total construction cost was prepared by the Program Management Consultant, and is presented in their report, *Denny Way/Lake Union CSO Project, Preferred Alternative - Concept Level, Construction Cost Estimate, September 17, 1997.* This cost estimate was updated later to reflect the October 1997 *Design Report and Preliminary Design Drawings* prepared by Black & Veatch. Table 2-1 lists the most probable construction cost for the Contract A components of the Denny Way/Lake Union CSO Control Project. The expected accuracy of the budget cost estimate is defined as +30% to -15%.

Table 2-1
Contract A: Most Probable Construction Costs

Contract A:	Cost Estimate
Elliott West CSO Control Facility	21,156,000
Site Work For Elliott West CSO C.F.	996,000
Mercer Street Tunnel	27,137,000
East Portal	2,590,000
West Portal	1,451,000
Outfalls	9,360,000
Public Art Myrtle Edwards Park	167,000
Total Anticipated Construction Cost	62,857,000

3. CSO Control Requirements

Ecology has adopted a number of regulations pertaining to municipal waste discharges, including regulations pertaining to combined sewer overflows. The regulations are outlined in WAC Chapter 173-245, which imposes a number of CSO control requirements, including the following:

- An average of one untreated overflow event per outfall per year.
- Total suspended solids (TSS) reduction.
- Disinfection.
- Compliance with applicable water quality standards.
- Effluent settleable solids limit.

The specific CSO control requirements are described below.

3.1 Treated CSO Control System Definition

The CSO treatment system consists of the Mercer Street Tunnel; the Elliott West CSO Control Facility; and either the Effluent Discharge Line and the Elliott West CSO Outfall or the EBI, through the Interbay Pump Station to the North Interceptor and the West Point Treatment Plant. The system has two treated discharge outfall locations: West Point Outfall and the new Elliott West CSO Outfall.

3.2 CSO Discharge Frequency

The project will result in a combination of storage and CSO treatment facilities for control of untreated discharges to meet the state requirement of one untreated discharge event per year (i.e., to control King County's Design Storm 6). A CSO project that controls Design Storm 6 either by storing the combined sewer flows and conveying them to a treatment plant (West Point) for treatment and disposal, or by providing CSO treatment before discharge, will meet state CSO treatment requirements.

3.3 CSO Treatment and Storage

The state CSO regulations allow a combination of storage and treatment for controlling untreated discharges to meet the state limit of one untreated discharge event a year. Flows in excess of storage capacity of the Tunnel (7.2 million gallons) and the conveyance capacity of the EBI will receive floatable material removal, disinfection, and dechlorination prior to discharge through the new Elliott West Outfall.

3.4 Untreated CSO Discharges

The state allows only one untreated discharge event of annual average rainfall per year per outfall. Flows from storms greater than King County Design Storm 6 will result in one annual untreated discharge event at the new Denny Way CSO outfall extension.

3.5 Floatable Material Control

The state regulations require submerged offshore discharges to reduce the aesthetic impacts of CSO discharges. Although there is no specific requirement for floatable material control, the project will control discharge of floatables through the Elliott West outfall to reduce aesthetic impacts. Floatable materials consist of wastewater components whose density is nearly the same or less than water, such as wood, paper, light metals, polystyrene, rubber, and plastic objects. Control of such objects will be achieved by providing vertical screens.

3.6 Suspended Solids Removal

The state requirement is for the Denny system to achieve a minimum system wide suspended solids removal of 50 percent calculated on an annual basis. Suspended solids removal will be provided by storing flows in the Mercer Street Tunnel and conveying them to the West Point Treatment Plant. The West Point Treatment Plant has a primary treatment and disinfection capacity of 440 mgd, and can also provide 300 mgd of secondary treatment. All CSO flows stored and diverted to the West Point plant will receive an average of 85 percent total suspended solids (TSS) removal, disinfection, and dechlorination before discharge.

The estimated annual total system CSO influent TSS is 364,000 pounds based on an annual CSO volume of 550 million gallons and an average TSS concentration ranging from 80 to 120 mg/L. Total annual discharges from West Point and the Elliott West CSO outfalls will be less than 50 percent of the total system CSO influent TSS, calculated on a mass (pounds of TSS removed) basis.

3.7 Settleable Solids

The state limit for effluent settleable solids discharge is 0.3 mL/L/hr. Application of the effluent settleable solids limit as a short-term monthly average is inappropriate for intermittently operating CSO treatment facilities. A more appropriate method is to define a maximum effluent settleable solid value, which will provide assurance that the long-term average of all events will meet the standard. The effluent settleable solids limit will meet the long-term geometric mean of 0.3 mL/L/hr with a maximum limit of 2.0 mL/L/hr per event. The 2.0 mL/L/hr limit corresponds to the 95 percent confidence limit based on analysis of Carkeek Park data. The DOE settleable solids criterion is based primarily on aesthetic considerations.

3.8 Fecal Coliform

The project will include chlorination to meet the Class A marine water quality standards for chronic fecal coliforms. The Elliott Bay fecal coliform level chronic limit cannot exceed 43 colonies per 100 mL for more than 10 percent of the samples (3 days a month). With an outfall chronic dilution factor of 10:1 and a peak day flow rate of 80 mgd, the project will meet the state water quality standards for chronic fecal coliform (43 colonies per 100 mL or less) for Class A marine waters with an "end of pipe" fecal coliform limit of 400 colonies per 100 mL for discharges through the Elliott West outfall. A fecal coliform limit of 400 colonies per 100 mL is the same limit as the technology-based limit applied to the West Point treatment plant.

3.9 Residual Chlorine

In order to meet Class A marine water quality standards for chronic residual chlorine, the Elliott Bay receiving water residual chlorine level shall be 0.0075 mg/L or less based on a peak day discharge. Based on predicted peak day volume discharge of 30 mg in a 24 hour period, and an outfall chronic dilution factor of 17:1, the proposed residual chlorine level is 0.1275 mg/L for "end of pipe" for Elliott West outfall discharges.

4. System Hydraulics

4.1. Hydraulic Model

A hydraulic model of the Denny Way/Lake Union CSO Control Project system has been developed. The model used is the proprietary software package XP-SWMM based on the widely used EPA Stormwater Management Model (EPA-SWMM). EPA-SWMM is composed of modeling blocks which allow the user to evaluate the hydrology, hydraulics, and treatment of stormwater and combined sewage. Two hydraulic engines are available: Transport and Extran. Transport is based on assumed gravity flow conditions. Extran routes hydrographs through a conveyance system using the full St. Venant equations. It is capable of evaluating the effects of backwater, surcharging, storage, pumping, and special hydraulic structures such as weirs. It can handle both open channel and pressure flow conditions.

XP-SWMM provides user friendly pre- and post-processors to the basic EPA-SWMM engines. It makes set up and evaluation of the system more efficient. It allows visual interpretation of the results, which in turn allows the user to make modifications to the system in a fraction of the time required by EPA-SWMM.

Because of the complex hydraulic structures of the Denny Way/Lake Union CSO project conveyance system, the Extran block of XP-SWMM has been used to evaluate the system.

4.2. System Performance Goals

As described in Chapter 3, the primary CSO performance goal for the Denny Way/Lake Union CSO Control Project is to reduce untreated discharges to once per year at the Denny Way Regulator. King County has used seven selected design storms for design and analysis of CSO conditions and facilities since development of the *1988 CSO Control Plan*. The overflows predicted from computer simulation of the system with these storms were used to estimate the annual average overflows from the system.

Design Storm 6, a once-per-year storm, was chosen as the basis of design for the final Denny Way/Lake Union project to coincide with Ecology's one untreated discharge per year CSO control requirement. Treatment and pumping facilities within the project have been sized to meet project goals during Design Storm 6.

Design Storms 1 through 7 are useful tools for estimating CSO volumes and for sizing CSO facilities. In a sense, the seven design storms define operational requirements during "normal" rainfall events occurring in "average" years. However, Pump Stations, pipelines, and regulators in the Denny Way system must also be able to safely convey wastewater under more extreme flow conditions than those represented by the seven design storms’ records. In addition to the design storms, the results from an especially high-intensity storm that occurred November 3, 1978, were used to examine peak hydraulic capacity.

King County Design Storm 6 has been identified as the once per year runoff event and CSO treatment has been designed to prevent discharge through the existing Denny

Way CSO Outfall Extension during Design Storm 6. The City of Seattle has indicated that the Mercer Street Tunnel hydraulic grade line (HGL) should be lower than elevation 116 at the connection to the Denny Way system. Also, flows in the existing Lake Union tunnel should be reduced to prevent excessive surcharging of the 100 year old brick tunnel. Although it is in good structural condition, it is recommended that excessive surcharging be minimized.

The November 3, 1978 storm is considered the highest intensity storm of record for King County. The overall system was also evaluated for this storm to determine peak HGL's and to make sure flooding does not occur. The system was also evaluated under the worst case conditions when both Interbay and the new pumping station are not operating to ensure that the system hydraulics are capable of passing peak flows.

4.3. System Refinements

During the preliminary design, several changes were made to optimize the system hydraulics. The following alternatives or changes were made iteratively to the system as previously modeled, to optimize the system performance or simplify construction:

- The South Lake Union CSO, Central Trunk CSO, and the Lake Union Tunnel Regulator Station CSO pipelines entering the Mercer Street Tunnel Drop Structure were changed to 72 - inch diameter, and the slopes on the South Lake Union CSO line and the Lake Union Tunnel Regulator Station CSO line were changed to eliminate the need for two of the three vortex drops at the Mercer Street Tunnel Drop Structure.
- The Lake Union Tunnel Regulator Station weir elevation was decreased to elevation 113.0 to reduce the upstream water surface elevations and to minimize problems in the City's system.
- Alternative pipe sizes were proposed for the Denny Way Outfall Extension to reduce the headloss through the last section of pipe at emergency conditions.

During Final Design, further changes have been made to the system to optimize hydraulic performance. These changes will accommodate the new maximum capacity of 300 MGD and include:

- Lowering the emergency bypass invert to 106.0.
- Increasing the Elliot West Outfall and pipeline to 96-inch diameter.
- Increasing the Denny Way outfall extension to 120-inch diameter.
- Eliminating use of a Parshall flume for flow measurement.
- Adjusting weir and channel elevations and final pipeline diameters for Elliott West facilities.
- Changing the pump sizes and pump inlet and discharge pipe diameters.

4.4. Modeling Results

Tables 4-1 and 4-2 summarize the final design flows and hydraulic grade lines for the modified system respectively. The pipe diameter and slope changes at the Mercer Street Tunnel Drop Structure had very little effect on the overall system hydraulics. Lowering the weir at the Lake Union Tunnel Regulator station favorably impacted the upstream conditions.

The hydraulic model is being used to simulate an emergency condition without making conditions worse than the existing condition. County staff modeled the November 1978 storm and the high tide condition for the existing system. The modeling is being compared to the final design modeling, to determine that this condition is met. Final modeling will also include fine-tuning of the hydraulic model adjacent to the Denny Way Diversion Structure, based on work being performed concurrently by the Contract C consultant.

Table 4-1
Peak Design Flow

Location	Design Storm Flow, mgd	
	Design Storm 6, One untreated event per year	November 3, 1978 Storm, Emergency Condition
South Lake Union CSO Pipeline	36.4	77.9
Central Trunk CSO Pipeline	18.2	55.8
Lake Union Tunnel CSO Pipeline	58.4	113.0
Exist. Lake Union Tunnel at Western Ave.	34.4	61.0
Elliott West CSO Pipeline	68.2	32.5
EBI	80.5	152.6
84 inch System Drain	187.0	161.7
Elliott West Effluent Pipeline	263.6	63.0
Elliott West CSO Outfall	263.6	63.0
Denny Way CSO Outfall Extension	0	394.8

Table 4-2
Peak Hydraulic Grade Line Elevations*

Location	Design Storm Hydraulic Grade Line Elevation	
	Design Storm 6, One untreated event per year	November 3, 1978 Storm, Emergency Condition
Special Manhole	107.0	113.4
Mercer Street Tunnel	98.0	112.16
Central Trunk Diversion Structure	135.54	136.54
Lake Union Tunnel Regulator Station	113.55	114.51
Exist. Lake Union Tunnel at Western Ave.	108.42	114.2
Denny Way Diversion Structure	105.59	113.15
Denny Way Regulator Station	96.85	110.75
EBI MH 1	102.30	110.99
EBI Control Structure	99.36	111.81
Elliott West Effluent Channel	127.73	N/A
Elliott West Effluent Pipeline MH1	112.93	109.06

5. Overall System Operation

The Denny Way/Lake Union CSO Control Project has several modes of operation. System operation will be determined by the quantity of wastewater entering the system, the upstream and downstream conditions, and the tidal elevation. Below is a general description of each mode of operation described below.

5.1. Nonstorm Events

Weir elevations and gate positions are set so the planned improvements would have no influence on dry weather flows. The nonstorm event flows would continue to flow through the existing Central Trunk, existing Lake Union Tunnel, and the existing EBI. Water surface elevations in these pipes, under dry weather conditions, are below diversion structure weir elevations and no flow would be diverted into the planned facilities.

5.2. Elliott West CSO Control Facility Pump Station Operation

The Pump Station will normally be an unmanned station. Therefore, all control of the pumping station must be either automatic or manual from a remote location.

Normally, the Pump Station and Mercer Street Tunnel will be dry and will be ready for storing CSO flow from a potential storm event. During a storm event, wastewater levels will rise in the interceptors, overflowing weirs at several locations. Diversion gates in the existing Denny Way regulator will close which in turn signals the gates in the Lake Union CSO Tunnel Regulator to close, diverting flow to the Mercer Street Tunnel. Also, during a storm event, wastewater levels will rise in the Central Trunk and overflow weirs at the Central Trunk Diversion Structure. The overflow will be diverted into the Mercer Street Tunnel through CSO pipelines and begin filling the Tunnel from the upstream end. Flow entering the Pump Station from the Elliott West CSO pipeline and EBI flow into the Tunnel through the Pump Station Wetwell.

The Mercer Street Tunnel has approximately 7.2 million gallons of storage which is sufficient to capture the excess flow of most storms. As the tunnel storage capacity decreases, as measured by the Wetwell level at the Elliott West CSO Control Facility, the lead pumping unit will automatically turn on a adjustable speed pump.

The pumping unit will come on at minimum speed and will attempt to maintain a setpoint level in the Wetwell that will be slightly lower than the start elevation of the pumping unit. The stored tunnel flow will be pumped into the Pump Discharge Channel of the CSO Treatment Structure. If the capacity of the pumping unit at minimum speed is greater than the inflow rate, the Wetwell level will fall. At the selected stop elevation, the pumping unit will turn off and the Wetwell level will rise again. When the Wetwell level again reaches the start elevation, the pumping unit will restart. There will be sufficient volume within the Wetwell and Tunnel between the start and stop elevations to prevent rapid cycling of the pumping unit.

If the pumping capacity at minimum speed is less than the inflow rate, the Wetwell level will stay above the setpoint elevation. The capacity of the pumping unit will be increased until it lowers the Wetwell level to the setpoint level, at which time the pumping capacity will exactly match the inflow rate. On increasing or decreasing inflow rates, the Wetwell level will rise or fall from the setpoint causing a respective speed change in the pumping unit as required to maintain the setpoint level.

When the inflow rate exceeds the capacity of the lead pumping unit at full speed, the Wetwell level will rise. When the Wetwell level rises to the pump start elevation, a second adjustable speed pump will begin operation. The second pumping unit will match the speed of the first pumping unit. The capacity of the two pumping units should then exceed the inflow rate and the Wetwell level will drop. When the level reaches the setpoint elevation, both pumping units will slow down together until they exactly match the inflow rate. On decreasing inflows, the pumping unit speed will drop to its minimum flow attempting to maintain the setpoint elevation. When the speed of the two pumping units reaches the minimum speed setting, the Wetwell level will drop. If two or more pumping units remain at the minimum speed setting for an adjustable time, one of the pumping units will drop off line. The Wetwell will fill again and the speed of the remaining pumping unit will adjust to maintain the setpoint elevation.

If the inflow rate exceeds the capacity of two variable speed pumping units, the third through the sixth units will start in a similar manner. When operating in the automatic mode with two or more adjustable speed pumps in operation, all units will operate at the same speed.

When starting or stopping pumps, a time delay will be initiated to allow the Wetwell to recover before starting or stopping additional pumps.

At the end of the storm event, the Wetwell level will be somewhere between the start and stop elevations. When the capacity of the EBI allows, the Elliott West CSO Control Facility Pump Station will be automatically switched from the CSO treatment and discharge mode to tunnel dewatering mode.

5.3. CSO Treatment and Discharge Operation

Treated discharge will occur when Tunnel storage approaches its capacity and there is insufficient EBI conveyance capacity to accept additional flows. All stored CSO flow from the Mercer Street Tunnel will be pumped into the CSO Treatment Structure Pump Discharge Channel. The flow rate will be measured by magnetic flow meters located in the pump discharge pipes.

As the flow rises in the Pump Discharge Channel past a set point, the mechanically cleaned screens will be activated. After the flow passes through the screens, it enters the Effluent Channel. Sodium hypochlorite will be injected at the end of the Effluent Channel, and the chlorinated effluent will flow by gravity through the Elliott West Effluent Pipeline.

5.4. Untreated Discharge Event Operation

Design Storm 6, the one-event-per-year storm, was the design basis for the Denny Way/ Lake Union CSO control system improvements. Untreated discharges will occur during storms greater in intensity and length than Design Storm 6. Once all downstream conveyance capacity, upstream and tunnel storage capacity, and CSO treatment capacity have been exhausted during those larger storms, untreated discharge will occur at the Denny Way regulator station.

As the EBI fills, the water surface elevation in the interceptor will rise until it reaches the overflow weir elevation. Discharges will also occur via the existing overflow weir for the Lake Union tunnel and the existing weir and flap gate assembly for the Denny local sewer. If these facilities are insufficient to relieve the excess flow, the water surface elevation will continue to rise until it reaches a preset level, at which time the overflow gates in the Denny Way regulator station will open to more quickly relieve the system. The overflowing wastewater will be discharged through the Denny Way CSO Outfall Extension into Elliott Bay. Flows discharged through the Denny Way CSO Outfall Extension will not receive floatables control or disinfection. However, flows being discharged through the Elliott West Outfall will continue to receive floatables control and disinfection.

5.5. Mercer Street Tunnel Dewatering Operation

In the Mercer Street Tunnel dewatering mode, the sluice gate on the EBI diversion will close, isolating the Wetwell and Tunnel from the EBI. A sluice gate in the Pump Discharge Channel will open, allowing water from the Pump Discharge Channel to flow back into the EBI. Pumping units will be started and speed adjusted remotely to control the rate at which the Pump Station dewaters the tunnel. The water level in the EBI upstream of the Elliott West CSO Control Facility will be monitored to determine the pumping rate.

When the Tunnel is completely dewatered, the main pumping units will be turned off based on water surface level. A low level float switch will prevent the pumping units from accidentally operating when the Wetwell level is below the low level shutoff elevation. The sluice gate on the EBI Diversion will open.

Final dewatering of the Wetwell will be performed with self-priming dewatering pumps located in the dry pit with their suction piping reaching to a sump in the Wetwell floor. The dewatering pumps will be operated manually, remotely or automatically based on water surface level to completely dewater the Wetwell. A service platform will be provided in the Wetwell to allow washdown of the Wetwell. Access hatches over the Wetwell will be provided for manual cleanup of excess rags and debris from the Wetwell, should it be required.

5.6. Emergency Operation

If the Elliott West CSO Control Facility Pump Station loses power during a storm event and the Mercer Street Tunnel storage capacity is full, the Wetwell level will continue to rise. When the elevation exceeds the bypass pipe invert, flow will begin to enter the Emergency Bypass pipeline. This pipeline will allow wastewater to flow from the Wetwell directly to the Elliott West Outfall. During this condition, the Wetwell will be surcharged.

An emergency generator will be provided at the Elliott West CSO Control Facility to supply power to controls, lights, sump pumps, and the sluice gates during the power failure.

6. Elliott West CSO Control Facility - Basis of Design

6.1 Elliott West CSO Control Facility

The Elliott West CSO Control Facility will include three major structures:

- Pump Station.
- CSO Treatment.
- Chemical Storage and Odor Control.

6.1.1 Pump Station

The Pump Station structure will consist of two major components:

- Wetwell.
- Drywell.

6.1.1.1 Wetwell. The Pump Station Wetwell will receive flows from the Mercer Street Tunnel, and from the Elliott Bay Interceptor (EBI) through the Elliott West CSO Pipeline. The water level surface elevation in the Mercer Street Tunnel will be controlled by the Wetwell water level. In order to maximize storage in the tunnel during peak flow, the Wetwell level will have to be as high as possible without surcharging the east portal of the tunnel or the EBI. For the preliminary design, a normal Wetwell level elevation of 98.0 feet has been used.

The Wetwell will be designed to conform to the latest edition of the Water Environmental Federation design standards and the Ecology “orange book”. Wetwell dimensions will be kept to a minimum through the application of variable speed pumping. Two trash pumps will be installed in the sump at the end of the Wetwell to allow complete dewatering following a storm event.

An emergency bypass pipe will be installed at invert elevation of 106.0 between the Wetwell and the Elliott West Effluent pipeline to allow partial diversion of Mercer Street Tunnel flow to Elliott Bay in the event of a power failure. The bypass flow will be 156 mgd at annual maximum tide elevation of 107.1 (Metro Datum). The bypassed flow will be discharged untreated into Elliott Bay. Backflow is prevented by a tide valve.

The displaced air during filling will be treated for odor control as described in Section 6.1.3.2, Odor Control.

The Wetwell will be equipped with hatches and slabs to allow access of equipment and maintenance personnel into the tunnel for inspection and cleaning. Stairs and intermediate platforms will be provided for access to the Wetwell. The Wetwell will have a space classification of Class 1, Division 2, and will be equipped with ventilation and lighting.

6.1.1.2 Drywell. When the flows exceed the storage capacity of the Tunnel or when the storm event is over, flows will be pumped from the Wetwell into the Pump Discharge

Channel. Flows are then released into the EBI for conveyance to the West Point Treatment Plant.

The Pump Station will be configured as a simple lift station with each individual pump discharging to the Pump Discharge Channel. Total station capacity will be 300 mgd, achieved with installation of the seventh pump. The Pump Station will be designed to allow routine servicing of pumps in-place and with provision for pump removal with cranes and hatches. An elevator and stairs will be provided for access by maintenance staff. The Pump Station will have five levels:

- Pump Level.
- Intermediate Level.
- Motor Level.
- Ground Level.
- Mezzanine Level.

6.1.1.2.1 Pump level. The pump level will house the six vertical dry pit centrifugal solids-handling sewage pumps and the elevator equipment room, with space for a future pump. Three jib cranes will be provided for pump removal for maintenance, with room provided for a fourth.

Each pump will be provided with an adjustable frequency drive unit located on the ground level. Each pump will have a capacity of 41.67 mgd, with a total dynamic head of 48 feet. Flow measurement will be achieved by magnetic flow meters in each pump discharge line Each pump will have a knife gate on the suction piping and a knife gate and anti-siphon valve on the discharge piping. The inlet piping will be 42 inches and the discharge piping 36 inches in diameter. The discharge piping will terminate in the Pump Discharge Channel. Table 6-1 lists the pump design criteria.

Table 6-1
Pump Design Criteria

Number	6 (with space provided for 7th future)
Type	Non-clog vertical centrifugal
Capacity (each), gpm	28,935
Speed, rpm	505
Head, feet	48
Motor size, horsepower	400
Electrical supply, volts/phase	480/3
Pump drive type	Adjustable frequency drives

Wetwell dewatering pumps and Drywell sump pumps will also be provided on the pump level. Table 6-2 lists the Wetwell dewatering pumps and Drywell sump pumps design criteria.

Table 6-2
Wetwell Dewatering Pumps and Drywell Sump Pump Design Criteria

Function	Wetwell Pump	Drywell sump pumps	
Purpose	Dewatering	Normal	Emergency
Number	2	2	1
Type	Dry pit submersible	Sump pump	Sump pump
Capacity (each), gpm	1000	75	1000
Speed, rpm	1775	1740	1775
Head, feet	65	65	65
Motor size, horsepower	40	10	40
Electrical supply, volts/phase	480/3	480/3	480/3
Pump drive type	Constant speed drives	Constant speed drives	

6.1.1.2.2 Intermediate level. The intermediate level will house the pump shaft support and bearing housings. Floor hatches will be positioned adjacent to the shaft to allow removal of the pumps.

6.1.1.2.3 Motor level. The motor level will house the six pump motors, with space for a seventh motor, and floor hatches adjacent to the motors to allow removal of the pumps.

6.1.1.2.4 Ground level. The ground level will contain an Electrical Room, adjustable frequency drives, and small rooms for janitor storage, sampling equipment, and lavatory. The Electrical Room will house the switchgear, a motor control center, an emergency generator, and a programmable logic controller system. Maintenance staff will enter the Pump Station through this level. An overhead bridge crane and a rollup door for the removal of equipment will also be located on the ground level.

6.1.1.2.5 Mezzanine level. The mezzanine level will contain the Mechanical Room which will house the heating and ventilation equipment for the Pump Station.

6.1.2 CSO Treatment

The Elliott West CSO Control Facility will provide the following CSO control processes:

- CSO storage control.
- Pumping.
- Floatable material removal.
- Disinfection and dechlorination.
- Odor control.

6.1.2.1 Floatable Material Removal. The Pump Discharge Channel will be equipped with fixed vertical screens for removal of floatable material. As flow is pumped from the

Wetwell, the water level in the channel will rise until the flow passes through weir-mounted mechanically cleaned vertical screens, equipped with rake mechanisms that will return the floatable material retained on the screen to the Pump Discharge Channel. In case of plugging or other emergency, the flow will overtop the screen. After a storm event, the floatable material from the Pump Discharge Channel will be drained into the EBI. Any grit or settled solids will be removed by a manually-operated washdown system into the EBI. The recommended screen design criteria are listed in Table 6-3.

Table 6-3
Screens Design Criteria

Type	Vertical
Number of screens	3
Clear opening between bars, inches	0.16
Bar size, inches	0.16
Dimensions, length x height, feet	29 by 3
Maximum flow through screens, mgd	300
Maximum head loss, inches	33
Cleaning mechanism drive	Hydraulic rake

6.1.2.2 Disinfection And Dechlorination. All flows to the Elliott West Outfall will be disinfected. Sodium hypochlorite will be the disinfectant of choice. Sodium bisulfite will be used for dechlorination. The disinfection and dechlorination facilities are described in Section 6.1.3, Chemical Storage and Odor Control.

Mixers will be used to mix the sodium hypochlorite into the flow at the effluent end of the Effluent Channel before discharge to the Elliott West Effluent Pipeline. At a flow rate of 300 mgd, the chlorine contact time in the pipeline will be in excess of 5 minutes.

Sodium bisulfite will be injected for dechlorination at the Dechlorination Injection Structure upstream from the Transition Structure. Dilution water would be added to maintain a minimum velocity of 2 feet per second in the 2-inch sodium bisulfite feed line. A 6-inch sleeve or double-containment pipe will be used to contain chemical leaks and to provide protection from aboveground loads.

Sodium bisulfite will be pumped to a day tank to be located at the Denny Regulator. Metering pumps will be located there, and transfer pumps will be located in the Chemical Storage Area.

6.1.3 Chemical Storage And Odor Control Area

The Chemical Storage and Odor Control Area consists of the following components:

- Storage and feed equipment for sodium hypochlorite.
- Storage and transfer equipment for sodium bisulfite.
- Odor Control equipment for wetwell and CSO Treatment Structure

6.1.3.1 Chemical Storage Area. The Chemical Storage Area will house the storage and feed equipment for sodium hypochlorite and storage and transfer equipment for sodium bisulfite. The sodium hypochlorite area will be covered, but not completely enclosed. The sodium bisulfite area will be totally enclosed due to the need to prevent bisulfite crystallization, which occurs at temperatures below 40°F. A concrete containment area with a sump will be provided to contain chemical spills. Chemical feed or transfer pumps will be installed above ruptured tank liquid level. Tank overflow and other liquids that collect in the sump will drain by gravity to an exterior vault. Discharge from the sump will be controlled by a manual valve. A high level alarm will notify the plant control system when the liquid level in the sump reaches a predetermined level. A chemical unloading station with valves and quick disconnect fittings will be provided for filling the chemical tanks.

6.1.3.1.1 Sodium hypochlorite design criteria and equipment. The sodium hypochlorite facility will include three metering pumps, two bulk storage tanks, piping, and appurtenances. The metering pumps and storage tanks will be located within the Chemical Storage Area.

Chemical metering pumps will be sized for the expected maximum and minimum dosages based on the design flow rate. The chemical storage tanks will be sized to provide approximately two days of storage at maximum dosage for the maximum storm bypass flow, with a return period of one year or less. Since fresh sodium hypochlorite (NaOCl) should not be added to the existing supply, at least two tanks must be provided. Each tank will have capacity for two 2,500-gallon shipments of chemicals.

The metering pumps will be hydraulic diaphragm type. Each unit will be equipped with a speed silicon-controlled rectifier (SCR) drive for a DC motor as well as a stroke-length adjustment controller and with automatic controls which will adjust the chemical delivery rate based on flow rate. The metering pumps will feed NaOCl from the storage tank to the effluent channel. Induction mixers similar to Water Champ will mix the chlorine into the CSO. Table 6-4 lists the design criteria for the sodium hypochlorite system with dosages set by operations staff.

6.1.3.1.2 Sodium bisulfite design criteria and equipment. The dechlorination facility will include two transfer pumps, two metering pumps, two bulk sodium bisulfite storage tanks, a day tank, piping, and appurtenances. The transfer pumps and bulk storage tanks will be located in the Chemical Storage Area. The metering pumps and day tank will be located at the Denny Regulator. Table 6-5 lists the design criteria for the sodium bisulfite system.

Chemical metering pumps will be sized for the maximum and minimum expected dosages for flows based on the design plant rate. Each tank will have capacity for two 2,500-gallon shipments of chemicals. The metering pumps will be hydraulic diaphragm type equipped with a speed silicon controlled rectifier (SCR) drive for a dc motor as well as a stroke-length adjustment controller.

Table 6-4

Sodium Hypochlorite Feed System Criteria

Feed System Component	Design Criteria	
Delivery Form Design Basis*	NaOCl: 12.5%, 1.04 lb Cl_2/gal NaOCl: 8%, 0.67 lb Cl_2/gal	
Sodium Hypochlorite Feed Requirements	Max Daily	Maximum Hydraulic
Contact Time, min Dosage, mg/L Flow Hypochlorite Feed Hypochlorite Feed	28.6 25 28 mgal 5,840 lbs. 8,715 gal	5 25 300 mgd 2,605 pph 3,890 gph
Feed Points	Effluent Channel	
Storage Bulk Location Number of tanks Capacity, each, gal Dimensions, dia x ht, ft. Type Instrumentation	 Chemical Storage Area Building 2 7500 10 x 12 FRP Sight gage, level transmitter 4-20 mA	
Metering Pumps Location Number of pumps Type Range, each gpm Motor Controls- Local Remote	 Chemical Storage Area Building 3 (2 duty, 1 standby) Hydraulic diaphragm 1.1 - 32 3 hp, 480 V, 3 pH, 60 Hz "On-off-remote" with SCR speed rate set. Stroke adjustment "On-off" with 4-20 mA flow pacing signal to control pump flows	
Alarms	Diaphragm failure alarm circuit to motor cutout and system alarm to control panel	
Mixers Location Number Type Motor Controls- Local Remote Alarms	 Mixing Chamber 2 (1 duty, 1 standby) Induction 15 Hp, 480 V, 3 phase, 60 Hz "On-off-Remote" "On-off" interlocking with pumps Failure	

* Based On 8% NaOCl due to degradation.

Table 6-5

Sodium Bisulfite Feed System Criteria

Feed System Component	Design Criteria	
Delivery Form	$NaHSO_3$: 38%, 4.169 lb/gal	
Sodium Bisulfite Feed Requirements	Max Daily	Maximum Hydraulic
Dosage, mg/L Flow Bisulfite Feed Bisulfite Feed	54 28 mgal 12,610 lbs 3,025 gal	54 300 mgd 5,630 pph 1,350 gph
Feed Points	Dechlorination Injection Structure	
Storage Bulk Location Number of tanks Capacity, each, gal Dimensions, dia x ht, ft. Type Instrumentation	 Chemical Storage Area Building 2 5500 10 x 10 FRP Sight gage, level transmitter 4-20 mA	
Metering Pumps Location Number of pumps Type Range, each gpm Motor Controls- Local Remote	 Denny Regulator 2 (1 duty, 1 standby) Mechanical diaphragm 0.4 - 23 3 hp, 480V, 3 pH, 60 Hz "On-off-remote" with SCR speed rate set. Manual stroke adjustment "On-off" with 4-20 mA flow pacing signal to control pump flows	
Transfer Pumps Location Number of Pumps Type Flow, each gpm Controls- Local Remote	 Chemical Storage Area pumps 2 (1 duty, 1 standby) Centrifugal diaphragm 5-25 On-off-remote On-off	

Table 6-5 Continued

Sodium Bisulfite Feed System Criteria

Day Tank Location Number Capacity, gallons Type Instrumentation	 Denny Regulator 1 1,700 FRP Sight gage, level transmitter 4-20 mA
Alarms	Diaphragm failure alarm circuit to motor cutout and system alarm to control panel
Mixers Location Type	 Dechlorination Injection Structure Static

The metering pumps will be provided with automatic controls which will adjust the chemical dosage based on flow rate. A computer adjustment will be applied to calculate the flow based on the increase or decrease in storage in the pipeline between the Pump Station and the point of injection. The change in storage will be monitored by a pressure element located near the bisulfite injection point. The operator can adjust the dosage multiplier through digital controls. The metering pumps will feed sodium bisulfite from the day tank to the Elliott West Outfall pipeline.

The dechlorination (sodium bisulfite) injection structure must be constructed upstream of the Elliott West Outfall for mixing of the bisulfite into the treated discharge. Injection upstream from the Outfall Transition Structure will allow residual chlorine monitoring in the Transition Structure. The day tank will receive sodium bisulfite through a 2-inch feed pipeline from the Elliott West CSO Control Facility Chemical Storage Area. A diffuser and mixer will be used to mix the sodium bisulfite into the Elliott West Outfall pipe at the injection structure. Chapter 8, Outfall - Basis of Design, describes the dechlorination injection structure in additional detail.

6.1.3.2 Odor Control. The Elliott West Facility has two separate areas that will require odor control: the Wetwell and the CSO Treatment Structure. The Wetwell will share a common headspace with the EBI Control Structure, which will be subject to continuous odor emissions from the interceptor sewer during normal flows. The CSO Treatment Structure; which houses the Pump Discharge Channel, screens, Effluent Channel, and mixing chamber; will be subject to high turbulence and emissions when in operation.

The Odor Control will be provided by two Phoenix™ carbon systems; one for the Wetwell and one for the CSO Treatment Structure. The Phoenix carbon system directs the air through the carbon canisters which convert H_2S to H_2SO_4. The carbon is regenerated on-line, resulting in no down time. The units will be housed in the Odor Control Area adjacent to the Chemical Storage Area, and will be covered but not completely enclosed.

A Phoenix^{TM} carbon system will treat 11,000 cfm of air from the Wetwell. The carbon unit will be designed to provide 0.5 air changes per hour for the Wetwell and Tunnel when the facility is not in operation and 15 air changes per hour during storm events with the Wetwell 80% full. A supply fan will be used to provide fresh air makeup when the tunnel is full and when personnel enter the space.

A Phoenix^{TM} carbon system will be provided to treat 11,000 cfm of intermittent air flow from the CSO Treatment Structure during outfall discharge and Tunnel dewatering. Although the wastewater will be diluted during storm flows, the high turbulence induced by screens, chlorine mixers, and the Effluent Channel may result in odor emissions. The carbon units will provide 12 air changes per hour to make the CSO Treatment Structure suitable for human occupancy. The Phoenix system will be activated only when pumps are operating or when maintenance staff enter this area. Mechanical louvers will be used to provide fresh air makeup.

6.1.3.3 Design Parameters

The following summarizes the ventilation design parameters for the Elliott West CSO Control Facility Wetwell and CSO Treatment Structure.

- The ventilation system for the Wetwell will operate continuously to provide ventilation when the Wetwell is in operation and to provide ventilation when the Wetwell is not being used to insure that corrosive gases do not build up in the Wetwell. The ventilation system will be designed to provide 15 ac/hr when the Wetwell is in use and 80 percent full.
- The Wetwell and Tunnel will be ventilated at a rate of 0.5 ac/hr when the Wetwell is not in operation. This level of ventilation will insure air circulation and prevent the build up of corrosive gases. The same fan will be used to ventilate the Wetwell when it is both empty and full.
- The ventilation system for the CSO Treatment Structure will be operated while the facility is in operation. It will be started when the pumps are initially activated and shut down after the CSO Treatment Structure has been cleaned. The ventilation system will be designed to provide continuos ventilation at a rate of 12 ac/hr.
- The ventilation system for the Wetwell and CSO Treatment Structure will be connected to the light switches. If the ventilation system is not on, it will be turned on when the light switch is turned on. This is an added safety measure to insure workers are not entering a potentially hazardous area.
- No additional ventilation system will be provided below the first platform in the Wetwell. To access these areas, confined space entry procedures will have to be utilized.
- LEL, H_2S, and O_2 meters will be placed outside the entrance to the Wetwell and both entrances to the CSO Treatment Structure.
- Heating or dehumidifying equipment will be evaluated for the CSO Treatment Structure to prevent freezing and condensation.

6.2 Electrical

6.2.1 Primary Electrical Power Supply. The Elliott West CSO Control Facility will receive 480 volt electrical service from Seattle City Light through two 2,500kVA pad mounted substation type transformers located on a slab at grade east of the CSO Treatment Structure. Each transformer will be powered from an independent feed from the Broad Street Substation.

6.2.2 Alternative Power Supply. A single substation (Broad Street) will supply the power to the site. However, there will be two separate electrical feed lines from a single power pole.

A 150 kW emergency generator set will be provided to energize critical equipment such as the sump pump, gates, and dewatering pumps during a power outage. In addition, standby power will be provided for lighting, controls, and telemetry.

6.2.3 Electrical Distribution. The transformers will feed an indoor 480-volt split-bus switchgear line-up, with a main-tie-main configuration. Incoming cables from the transformers will be routed in an underground ductbank. The available fault current at each switchgear bus will be approximately 52,000 amperes.

Under normal operating conditions, the main breakers will be closed and the tie breaker will be open. In the event of a utility feed failure, the corresponding main breaker will open and the tie breaker will close. When the power supply is restored, the tie breaker will open and the main breaker will close.

The switchgear will feed six pumps through drawout, low-voltage power circuit breakers. The switchgear will also power the Motor Control Center located in the Electrical Room. The main, tie, and feeder breakers will be electrically operated. The switchgear and motor control centers will be in gasketed NEMA Type 1 indoor enclosures. The Preliminary Design Drawings show the electrical one line diagram for power distribution.

The Motor Control Center will supply power to all building systems and other equipment at the Pump Station. In the event of a power failure, critical loads will be powered from a standby power generator through an automatic transfer switch in the motor control center.

6.2.4 Lighting. Indoor lighting will consist of industrial fluorescent fixtures in areas of low ceilings and metal halide high-intensity discharge fixtures in areas of high ceilings. Some fixtures will be provided with rechargeable battery backup. Emergency light wall packs will be provided for areas where the battery packs can not be provided. The Wetwell will not be provided with lighting.

Wall-mounted high-pressure sodium fixtures will be used in outdoor areas and over the entrance doors. Parking and roadway lighting will be provided by pole-mounted high pressure sodium fixtures. Outdoor lighting will be controlled by an “on-off-auto” selector switch. Photo-cells will be utilized in the “auto” mode.

6.2.5 Telephone, Fire Alarm and Security

6.2.5.1 Telephone. Telephone service will be provided.

6.2.5.2 Fire Alarm. A fire detection and monitoring system will be provided.

6.2.5.3 Security. A security system will not be provided. The facility will be fenced with access gates.

6.3 Structural

6.3.1 Geotechnical Considerations

6.3.1.1 Subsurface Conditions. Subsurface investigation included four borings and six cone penetrometers. In general, the subsurface consists of about 25 to 30 feet of loose to medium-dense granular fill and beach deposits over about 25 to 30 feet of medium-stiff to hard glaciolacustrine deposits consisting of clayey silt and silty clay. The glaciolacustrine deposits are underlain by very dense to hard glaciomarine drift varying from sandy silty clay to gravelly silty sand.

Monitoring wells were installed in three borings to evaluate groundwater conditions. Groundwater was observed in the fill and beach deposits at elevation of about 105 feet and in the granular glaciomarine drift at 110 feet. Groundwater variations of about 5 feet have been observed in other wells in the glaciomarine drift.

6.3.1.2 Foundation Systems. Both shallow and deep foundations were considered for the Elliott West CSO Control Facility because of the subsurface conditions and the differences in structure types, design loads, and bottom elevations.

6.3.1.2.1 Pump Station. Construction of the Pump Station Drywell and Wetwell will require a 50- to 60-foot deep excavation through the fill and beach deposits into the glaciolacustrine and glaciomarine drift deposits. Watertight temporary shoring will probably be necessary to control groundwater in the upper 25 to 30 feet. The bottom of the excavation may extend to granular water-bearing glaciomarine drift; however, the permeability of these deposits is likely to be lower than those of the fill and beach deposits. Lowering of the groundwater outside the excavation is not feasible because of the potential of damage to the adjacent roadway (Elliott Avenue West) and railroad tracks. Settlements could also occur as a result of the excavation.

The bottom of the Pump Station Wetwell and Drywell excavation is anticipated to extend into the glacial deposits, and no additional foundation support will be required. Construction of the West Tunnel Portal adjacent to the Pump Station will allow simultaneous construction of the Tunnel and Pump Station. The two-story Electrical and

Mechanical Rooms will be attached to the deep structure on one side and supported by piling on the other side.

6.3.1.2.2 CSO Treatment Structure. Construction of the CSO Treatment Structure will be similar to the Electrical Room. The structure will be made part of the deep structure on one side and supported by piling on the other side.

6.3.1.2.3 Chemical Storage and Odor Control Area. The Chemical Storage and Odor Control Area will be constructed on structural fill. The chemical storage tanks, odor control vessels, piping, and other appurtenances will be pile supported.

6.3.2 Structural Design. The Elliott West CSO Control Facility will be constructed of reinforced concrete with foundations as described in the preceding section. The facility will consist of two separate structures. The structures will be separated by expansion joints or physical space as follows:

- Pump Station Drywell, Wetwell, Electrical Room, Mechanical Room and CSO Treatment Structure.
- Chemical Storage and Odor Control Area.

Dead loads, live loads, wind loads, and seismic loads will be calculated according to the UBC of 1997. Roof live load will be 20 psi. The walkways and platforms loads will be 100 psi. The suspended floor slabs will be designed for 150 psi. The concrete strength will be 4,000 psi at 28 days. Reinforcing steel strength will be 60,000 psi.

6.4 Architectural

6.4.1 General Configuration. The Elliott West CSO Control Facility will be of Type II-N construction. The cast-in-place concrete structure will meet all requirements for fire rating between structures. The maximum building height will be 45 feet from the existing ground level.

The Chemical Storage and Odor Control Area will have an H-3 occupancy classification only if it is enclosed. It will contain storage facilities for two different chemicals.

Both the CSO Treatment Structure and the Pump Station will have S-2 occupancy classifications. Each component will be well within the maximum area limits for a sprinkled building.

The Pump Station will be the only multi-level structure, composed of five levels: the ground level, three basement levels, and a mezzanine (1120 s.f.). The lowest level will house the pumps. The intermediate level will contain support points for the long-motor drive shafts. The upper basement, or motor level, will house the motors. The ground level will consist primarily of high bay space with an overhead crane for removal and replacement of the motors and pumps. An overhead door will provide access for trucks to the crane bay. The eastern portion of the ground level will house the Electrical Room. Electrical equipment for the pump motors will be located in the crane bay. Space for the janitor closet, a lavatory, and a sample room/office will be located in the main portion of the ground level. A mezzanine above the Electrical Room will house the mechanical equipment to ventilate the station.

Two unusual features on the ground level will be the force main pipes from the pump to the CSO Treatment Structure, and an elevator to carry staff and tools from the ground level to the lower levels 50 feet below grade.

Access to the Wetwell will be through a stairwell on the south side of the Pump Station. Only one means of egress will be required from the basement levels of the Pump Station. The overall length of the station, combined with the length of the stair, will be at the limit for exit distance. If this exit length is increased in the later stages of the design, the stair will have to be enclosed and the exit walled. Two means of egress are required from the Electrical Room and the sodium bisulfite storage room.

The Pump Station and the CSO Treatment Structure will be connected. The connection will be through a vestibule to avoid a single door opening from one space into the other.

To facilitate crane operation and observation of the pumps, a railed opening will be provided in the floor of the ground level. The structural floor beams will intersect the opening. The floor openings on the motor and intermediate levels will be grated hatches, providing open floor space around each motor.

6.4.2 Architectural Character. The site along the busy Elliott Avenue West arterial is an area in transition from its former industrial and supply oriented use to commercial and mixed-use residential. Immediately to the west of the site is a rail yard and beyond that a shoreline park and Puget Sound.

The residential area to the east and above the site, and the view to the waterfront to the west of the site means that many residents will be looking at or across the roof of the building. The large, nearly square footprint of the structure will be rather large and uninteresting unless steps are taken to give it visual interest and scale. It is proposed to separate the roof into at least three and as many as six distinct elements, by different heights or shapes. Because the structures are being designed with separations, it is simpler to utilize different roof heights and forms than to make them all the same height.

6.4.3 Siting. The site is composed of a large land parcel south of the Mercer Street right-of-way and medium-sized parcel north of the right-of-way, and the former right-of-way. Currently, it appears that the Mercer Street Tunnel will project to the north edge of the right-of-way, making a Pump Station on the northern parcel the best location.

The zoning allows buildings to be located within 5 feet of the property line. Allowing the building to be close to the sidewalk will help ‘form’ the edge of the street and give pedestrians the sense that they are ‘somewhere’, even if they cannot actually enter the building.

The area to the west and to the north of the building will be fenced. Trucks will enter through a gate north of the building and drive around the building to exit the site. Access to the storage areas will be on the north side and with entry through doors on the south side of the building.

6.4.4 Architectural Materials

A recommended list of exterior and interior materials is presented in Table 6-6.

Table 6-6
Architectural Materials

Architectural Material	Recommendation
Exterior Wall Materials	• Masonry: Brick Veneer or decorative Concrete Masonry Veneer Units • Cast Stone concrete trim • Glass Block
Roofing Materials	• Membrane Roofing • Metal Roofing
Doors and Windows	• Aluminum frames and solid panes • Translucent Panel
Interior Wall Finishes	• Paint • Ceramic Tile at Lavatory, Janitor, and Sample Room
Floor Finishes	• Sealed Concrete
Stairs and Hand Railing	• Aluminum

6.5 Landscaping

6.5.1 Elliott West CSO Control Facility

6.5.1.1 Code Review. Landscaping for blank facades of buildings will meet the requirements of the City of Seattle Land Use and Zoning Code, Section 23.50.038, Industrial-Commercial Screening and Landscaping. Blank facades of buildings which front Elliott Avenue West and are within 20 feet of the street are required to provide one of the following types of landscaping:

- A hedge which will achieve a height of at least 5 feet within three years of planting and at least 10 feet at full maturity.
- Architectural trellises with vines attached to the wall, with a minimum height of 10 feet.
- A landscaped area or berm planted with trees, shrubs, and evergreen ground cover with coverage occurring within three years.

Surface parking for more than five vehicles on the north side of the building will require plant material screening from the abutting property.

6.5.1.2 Landscaping Approach. The intent of landscaping is to provide a setting which enhances the architectural structure of the station, screens undesirable elements or views, and meets City of Seattle and City of Seattle Engineering landscape code. Plant materials for the site will be low-water use and low maintenance type and will require an automatic irrigation system for establishment.

Landscape plantings adjacent to the building will be arranged to strengthen the building is form. Trees will be planted to provide relief to blank facades, to offer shade, and to provide a vertical complement to the architecture. Deciduous and evergreen shrubs and ground covers will be used to balance hard-surfaced areas and to soften the appearance of the building's foundation. A tall retaining wall on the west property line adjacent to the railroad tracks will have a minimum of a 5-foot planting strip planted with shrubs and vines to cover the wall. The wide planting strip on the north side of the facility will slope to the property line. The slope will be planted with a mixture of native trees, shrubs, and ground covers to establish erosion control. A swale will be provided at the toe of the slope for drainage. Surface treatment options of the swale will be explored with an emphasis on wetland plants. The south side of the facility will be sloped to the property line (right-of-way line of the abandoned street). Planting design will be similar to the north side planting strip.

Plants for all landscaped areas will be chosen for their hardiness and ease of maintenance. Soil amending and preparation will be based on soil tests. Irrigation will be by an automatic watering system.

A preliminary landscape plan will be prepared indicating plant locations, type, and size. Evergreen trees will be 6 feet in height, deciduous trees will have a 2-inch caliper, and shrubs will be at least 18 inches in height. Shrubs for screening the parking lots will be evergreens at least 30 inches high at the time of planting. Ground cover in one-gallon containers will be spaced 18 to 36 inches apart.

6.5.2 South Parcel Landscaping. During construction of the Elliott West CSO Control Facility, the 190 by 400-foot site south of the treatment facility will be used as the construction staging area. At the end of construction this area will be restored in accordance with permit requirements.

The site is within walking distance of the West Queen Anne neighborhood and is near a designated pedestrian path at Elliott Avenue West and West Mercer Street leading to the top of Queen Anne Hill. The site is flat with no distinct landscape features and is surrounded by light manufacturing and commercial establishments. Elliott Avenue and the Burlington Northern Railroad tracks on the east and west sides of the site generate considerable traffic noise. Two options were considered for possible use of this property.

One option will be to use the soil excavated from the facility and tunnel to create perimeter planting berms on the area's west, north, and south sides, with a lawn in the middle of the site. The site is not large enough for a baseball, softball, soccer, or football fields.

The other option, also with perimeter planting berms on the west, north, and south sides of the parcel, would incorporate basketball or tennis courts on the northern half of the parcel and a small play field on the southern half. Under both options the site would be fenced, with gated access from Elliott Avenue West.

Both of these uses may involve a zoning change from the current industrial-commercial classification.

6.5.3 Right-of-Way Improvements Along Elliott Avenue West

6.5.3.1 Code Review. Planned landscaping will meet street tree requirements of the City of Seattle Land Use and Zoning Code, section, 23.50.038, Industrial-Commercial Screening and Landscaping and the City of Seattle Engineering Department Standards. Trees will be planted in the 5-foot strip between the sidewalk and the curb or behind the sidewalk. Consideration will be given to planting trees along the entire length of Elliott Avenue West adjacent to the future development parcel south of the treatment facility. The tree selection will be reviewed and approved by the City of Seattle arborist.

6.5.3.2 Landscaping Approach. Street trees will provide landscape relief and shade for the pedestrians using the sidewalk. The 5-foot planting strip will be planted with low evergreen shrubs to give a sense of protection and interest along the heavily-traveled street.

6.6 Site Work and Utilities

Site work and utility improvements at the Elliott West CSO Control Facility will include the following:

- Construction of the Elliott West CSO Control Facility Building.
- Construction of retaining walls.
- Paving of sidewalks, driveways, access roads, and parking.
- Installation of the process piping (i.e., EBI, effluent pipe, and tunnel).
- Installation of utilities.
- Installation of fencing.
- Final grading.
- Installation of site utilities—water, sewer, and drainage facilities.

The Elliott West CSO Control Facility will be located on a vacant 2.9-acre lot recently purchased by the King County Department of Natural Resources. The property is located on the west side of Elliott Avenue West between the vacated rights-of-way of West Roy and West Republican Streets. The facility will be located in the northern portion of the site. It is assumed that the south edge of the West Mercer Street right-of-way will be the south edge of the project site.

The Elliott West CSO Control Facility building will be rectangular, measuring approximately 100 feet by 150 feet, with its long axis perpendicular to Elliott Avenue West. The building will be located about 15 feet from Elliott Avenue West. This leaves an approximately 35-foot access width between the west end of the building and the west property line. The ground floor will be at elevation 120.

6.6.1 Development Standards. Since the project lies within the City of Seattle, it will be subject to the standards of the following agencies:

- Seattle Engineering Department (water and sewer).
- Seattle Department of Construction and Land Use (drainage).
- Seattle Fire Department (access and fire flow).

The standard plans and specifications referred to within this memorandum are the *City of Seattle Standard Plans and Specifications for Municipal Public Works Construction.*

6.6.2 Roadway and Site Access. Access to the site will be from two locations off Elliott Avenue West; adjacent to the north side of the building, and adjacent to the building's south side. The existing crosswalks at West Mercer Street and Elliott Avenue West must be preserved, so the southern access will be located between the two crosswalks. At each access point, the curb radius will be about 25 feet and the driveway width will be approximately 30 feet. The Design Drawings show the proposed roadway plan.

6.6.2.1 Maintenance Access. Maintenance access depends on the types of vehicles serving the site and the necessary orientation of these vehicles to the building. It is assumed that two categories of trucks will serve the site: a 3-axle tractor/2-axle semitrailer combination (tanker truck) and a 3-axle single unit (boom/service truck).

A boom/service truck will probably be used for several purposes including the following:

- Removal of chemical storage tanks (north building side).
- Removal of carbon units (north building side).
- Removal of pumps (south building side).

It is assumed that the boom/service truck will not need a backing-up area to service the chemical storage tanks and the carbon units. It will have to back up through the coiling door and into the area above the Drywell for loading the pumps. The roadway along the south side will be sized assuming that a 30-foot boom/service truck could maneuver into a position perpendicular to the building within the 45-foot space between the building and the curb.

6.6.2.2 Chemical Delivery Access. A tanker truck will deliver chemicals to the storage tanks located along the north side of the building. It is assumed that the tanker truck will not need a backing-up area and that the chemicals can be transferred with the truck's long axis oriented parallel to the north side of the building. Tanker truck ingress, egress, and access around the building will be designed using the minimum turning path for a 55-foot vehicle.

6.6.2.3 Fire Department Access. The proposed site roadway layout satisfies the requirements of the Seattle Fire Department's (SFD) *Administrative Ruling 9.2,* which states:

- Access roads shall be provided within 150 feet travel distance to the most remote portion of the building.
- Fire department vehicle access roads shall be 20 feet wide.
- Turn radii shall be 25 feet inside of curb and 50 feet outside of curb.
- Maximum grade for access roads is 20 percent.

6.6.2.4 Roadway Pavement. Site roadway pavement will be 3 inches of asphalt concrete, Class B over 6 inches of crushed rock, Type 1, consistent with *Standard Plan No. 401.1*. Pavement edges will be curb and gutter consistent with *Standard Plan No. 410*. Minimum pavement slope will be 1 percent. The maximum pavement cross-slope will be 3 percent.

6.6.3 Site Work

6.6.3.1 Grading. Unsuitable site soils will be removed and replaced with structural fill according to the recommendations included in the site geotechnical report. Additional structural fill will be placed to bring the existing grade up to proposed subgrade elevation. The structural fill will be imported material as specified in the geotechnical report.

Since the Elliott West CSO Control Facility will be at elevation 120 and the existing grades at the north, west, and south edges of the site are at an approximate elevation of 110, a combination of retaining walls and sloped embankments will be used as transitions between the building/roadway areas and the adjacent properties as shown on Preliminary Design Drawings.

A portion of the existing retaining wall along Elliott Avenue West will be removed to accommodate construction. The north and south ends of the wall will probably remain in-place. A new retaining wall will be constructed along the west side of the facility. The west retaining wall will be full height over the portions adjacent to the roadway area and then step down to meet the existing grades along the north and south sides of the site. Slopes of 2:1 will fill the north and south margins of the site, sloping from the curb to grass-lined swales at the toe of the slope. The swales will be sloped to catch basins which will drain to the site stormwater system.

6.6.3.2 Fencing. The site will be fenced along each property line. The fence will include two 30-foot wide swinging chain link gates. Fence and gate will be consistent with *Standard Plan Nos. 450a* and *450c*. The SFD inspectors will determine whether a Knox key box will be required for access into the fenced area as part of their annual inspection program. If a box is required, King County will be notified in writing of the need to obtain a Knox key box.

6.6.4 Site Utilities

Site utilities described in this section are shown on the Preliminary Design Drawings and include potable water supply, sanitary sewer, and stormwater.

6.6.4.1 Potable Water Supply. Potable water will be delivered to the site through the existing 12-inch waterline along the west side of Elliott Avenue. The Seattle Water Department (SWD) will make all taps for water service and will supply, disinfect, and install pipes in the Elliott Avenue West right-of-way. The work on the site water supply will consist of extending the service connections from the property line to the building.

The *City of Seattle Standard Plans and Specifications for Municipal Public Works Construction*, the *Uniform Plumbing Code*, and the *Uniform Fire Code*, as modified by City of Seattle, will govern as the standard for the civil design portion of the site water supply.

6.6.4.1.1 Domestic water use. The size of the water supply depends on the projected water use. Since the facility has only one lavatory and no full-time employees, personal water consumption will be minimal. Water requirements for process systems (disinfection, etc.) and for maintenance (screen cleaning, etc.) have not been determined at this time. It is assumed that the total water use can be supplied through a 2-inch water supply line.

A water supply line of 2-inch copper tubing will be connected to the 2-inch building water stubout and extended outdoors under the access roadway to a backflow preventer assembly. The water supply line will be buried with a minimum soil cover of 36 inches, and will be equipped with a shutoff valve. The SWD will provide the connection between the new union at the pipeline and the 12-inch water main and install a water meter in the public right-of-way.

6.6.4.1.2 Fire flow. The building fire protection system will be served by a 10-inch supply line. The SWD will install the main line connection, a gate valve, a single check valve, and a trip meter, and will extend a ductile iron fire flow main to the property line. The main line will continue to an underground backflow preventer assembly housed in a vault set to grade. Beyond the backflow preventer, a 6-inch tee will be installed for a post indicator valve and a fire department connection installed in an underground vault. The 10-inch line will continue through the building foundation to the fire protection control area. The SFD will be responsible for inspections of all underground portions of the fire protection system.

6.6.4.2 Sanitary Sewer. The existing 12-inch sewer along the centerline of Elliott Avenue West will be the connection point for the project side sewer. Unlike the water supply connection, construction work off the property line can be performed by any registered sewer contractor. However, the Seattle Engineering Department (SED) will visually inspect the pipe prior to backfilling and will observe the watertightness testing. A “Side Sewer Permit” issued by the SED is required before work on the side sewer begins.

6.6.4.2.1 Design requirements. *The City of Seattle Standard Plans and Specifications for Municipal Public Works Construction* will govern as the standards for the project side sewer.

6.6.4.2.2 Side sewer. To comply with applicable standards, the side sewer will be at least 6 inches in diameter in the public right-of-way and at least 4 inches in diameter on private property. Side sewers must be not more than one pipe size smaller than the public sewer to which they connect (a side sewer connecting to a 12-inch public sewer may be no smaller than 10 inches in diameter). Side sewers can be concrete sewer pipe, PVC sewer pipe, or ductile iron pipe. The side sewer will be connected to the building sewer. The standards require at least 18 inches of soil cover over a side sewer. Soil cover over the side sewer will be at least 18 inches within the property lines, at least 30 inches at the property line, and at least 60 inches at the curb line. The project side sewer will cross an existing waterline, which requires at least 18 inches of vertical separation between the two pipes. Two test tees will be placed on the side sewer; one immediately adjacent to the main sewer and the other at the property line. The tee openings will be perpendicular to the side sewer slope. Sewer cleanouts will not be provided because the side sewer will not undergo an alignment change of 90 degrees or more, and its length will not exceed 100 feet. The side sewer will be connected to the existing sanitary sewer through a wye branch.

6.6.4.3 Stormwater. The developed site will cover approximately 1.3 acres, of which 0.8 acre will be impervious surfaces and 0.5 acre will be pervious. Stormwater will be collected and directed to the Wetwell or to an onsite detention system, then discharged to the sewer, if not to the Wetwell. Since the site is located in an area where no public storm drains are planned, the stormwater system will not be subject to maximum depth requirements.

6.6.4.3.1 Design requirements.

The DCLU requires all development, grading, and construction projects to have adequate stormwater drainage control and to provide a client assistance memorandum titled *Design Specifications for Private Drainage Systems.* DCLU requires a "Comprehensive Drainage Control Plan" (CDCP) for projects with more than 9,000 square feet of developmental coverage. A "Temporary Erosion and Sedimentation Control Plan", designed according to the *City of Seattle Best Management Practices Manual* and *DCLU Director's Rule 6-93*, must accompany the CDCP. The "Side Sewer Permit" must be issued by the SED before work on a private drainage system begins.

6.6.4.3.2 Stormwater collection. All roof downspouts will be directly connected to the site stormwater system and will not discharge onto the paved area. If the stormwater system includes detention, the downspouts will not need to be fitted with "P" traps. "P" traps will be required if discharge is to the Wetwell.

Runoff from paved surfaces will be directed to catch basins as shown on *Standard Plan No. 241*. Direct catch-basin-to-catch-basin connections will not be made; instead, each catch basin will connect to a main conveyance line. Each catch basin will be fitted with an outlet trap consistent with *Standard Plan No. 267*.

6.6.4.3.3 Stormwater detention. The site detention system will consist of approximately 200 feet of buried 48-inch, aluminized corrugated steel pipe which will have a detention volume of 2,800 cubic feet. The detention pipe will be sloped at least 0.5 percent to a flow-control device, and have a manhole at its end for venting and inspection. Applicable standards dictate at least 2 feet of soil cover over the detention pipe. The flow control structure will be a 48-inch-diameter manhole consistent with *Standard Plan No. 270.1a*. The detention pipe will reduce to a 30-inch pipe immediately ahead of the flow control structure. The 2-inch overflow device at the flow control structure will be set at an elevation consistent with the crown of the upstream end of the detention pipe.

6.6.4.3.4 Stormwater transport. Conveyance pipes between catch basins and the flow control structure can be concrete or PVC. The minimum pipe size will be 6 inches in diameter. The standards allow a maximum 50 percent slope and a minimum slope of 2 percent for these pipes. At least 18 inches of cover is required over pipes located on private property.

6.6.4.3.5 Stormwater discharge. Stormwater from the flow control structure will discharge to the side sewer near the property line. The pipe connecting the flow control structure to the side sewer will be of the same diameter as the side sewer. The flow control structure pipe will be connected to the side sewer through a wye. The invert elevation of the side sewer at the property line will be at least 1 foot above the crown of the sanitary sewer.

6.7 Mechanical

6.7.1 Air Conditioning. No industrial air conditioning system will be provided for the Elliott West CSO Control Facility.

6.7.2 Heating and Ventilation. Heating and ventilation will be provided for all levels of the Pumping Station at the rate of 6 ac/hr. In the Chemical Storage and Odor Control Area, the sodium biosulfite storage room is the only space that requires a heating and ventilation system. The Odor Control Area and the sodium hypochlorite room are open to the outside.

The ventilation requirements for the Wetwell and CSO Treatment Structure were discussed in Section 6.1.3.2. The lavatory and sample rooms will require 6 air changes per hour. Heating capacities were derived from the requirement to maintain 60° F space temperatures throughout the building.

6.7.3 Plumbing. The Pump Station ground level will contain a lavatory, sample room, and a janitor room which will require water supply connections. Additional plumbing fixtures will include emergency eye washes and showers, and a washdown water supply. A 30-gallon electric water heater will supply hot water for domestic uses. Cold water hose bibbs will be located throughout the Pump Station, the CSO Treatment Structure, and the Chemical Storage and Odor Control Area. All plumbing fixtures and general floor drains will discharge into the city sanitary sewer system. Table 6-7 shows the mechanical equipment.

6.7.4 Building Fire Protection System. A fire protection system will be installed for the entire facility, including the Chemical Storage and Odor Control Area, CSO Treatment Structure, and Pump Station. Fire protection measures will conform to NFPA 820 and local fire codes.

6.8 Instrumentation and Control

6.8.1 Controls. All control within the facility will be accomplished with a Programmable Logic Controller (PLC) which may also act as the interface to the King County Supervisory Control and Data Acquisition (SCADA) system. Within the PLC, each of the effluent pumps will be controlled by separate proportional controller logic. Dual level transmitters will be installed to measure and transmit the Wetwell bubbler level signal to the PLC. The high water level switch will be wired directly to two effluent pumps, bypassing the PLC.

A PLC will be used for automatic control of the following functions:

- Screening of floatable material based on Pump Discharge Channel water level.
- Chlorinating based on flows to the Elliott West Outfall.
- Dechlorinating based on chlorine dosage.
- Positioning of the Wetwell tunnel dewatering sluice gate during the tunnel dewatering mode based on EBI level at the Denny Regulator.
- Generating emergency power based on power feed.

The Pump Station will be provided with a bubbler-type Wetwell level monitoring system to indicate Wetwell level and to control the main pumping units and sluice gates. The control elevations are provided in Table 6-8. Locations of gates are listed in Table 6-9.

Table 6-9
Mechanical Equipment Schedule

Equipment Designation	Description	Service	Type	Material	CFM	S.P. in wg.
OCF-1	Exhaust Fan	Odor Control	Centrifugal	Fiberglass	11,000	8
OCF-2	Exhaust Fan	Odor Control	Centrifugal	Fiberglass	9,000	7.5
EF-1	Exhaust Fan	Ground Floor & floors to elev. 75	Centrifugal	Sheet Metal	35,000	4.5
MUA-1	Air Handler & Gas fired heating capability.	Make-up air & heating for Ground Floor & floors below to elev. 75	Centrifugal	Sheet Metal	35,000	3.25
SH-1	Space Heater	Room Heat	Electric Space Heat	Metal	900	-
EF-R	Exhaust Fan	Roof Exhauster	Vertical-Centrifugal	Stainless Steel	1,800	2.5
EF-2	Exhaust Fan	Sample Room	Centrifugal	Sheet Metal	400	0.75
EF-3	Exhaust Fan	Bathroom	Centrifugal	Sheet Metal	400	0.75

Table 6-10
Wetwell Control Elevations

Item	Elevation
High Water Alarm	100.0
Start Lead Pump	98.5
Setpoint	98.0
Stop Lead Pump	97.5
Low Water Alarm	76.0
Tunnel Invert	75.0
CSO Alarm (on rising Wetwelllevel)	68.0
Wetwell Floor	64.5

Table 6-11
Major Sluice Gates

Gate	Location	Type of Control	Modulating	Fail Position	Normal Position	Function
SG-1	Wetwell	Auto	No	Open	Open	Admits water from EBI into Wetwell. Closes in tunnel dewatering mode
SG-2	Pump Discharge Channel	Auto	No	Closed	Closed	Opens to allow water from Pump Discharge Channel to flow back into EBI
SG-3	Lake Union Regulator	Auto	No	in current position	Open	Closes to divert water to the Tunnel for storage
SG-4, SG-5, SG-6	East Portal	Manual	No	Open	Open	Closes to provide storage in upstream interceptors, opens quickly to flush Tunnel

6.8.2 Telemetry

The PLC will also transmit information such as alarms, flow rates, and other measurements through the King County SCADA system. In addition to the measurements described in the following section, the PLC will also receive the following inputs for telemetering:

- Sodium hypochlorite feed flow failure.
- Sodium bisulfite feed flow failure.
- Status (On/Off/Fail/Out-of-Service) for each raw sewage pump.

- Status (On/Off/Fail/Out-of-Service) for each dewatering pump.
- Status (On/Off/Fail/Out-of-Service) for the floatable material screen.
- Low level for each chemical storage tank and day tank.
- Low and high level alarm for the Wetwell.
- Smoke/fire detection system.

6.8.3 Sampling and Flow Measurements

6.8.3.1 Flow Measurement. The following flows will be measured, locally recorded, and telemetered to the West Point Treatment Facility:

- Treated effluent discharges into Elliott Bay will be measured by magnetic meters in the Elliott West CSO Control Facility and will include flow rate, duration, and volume.
- Stored tunnel flows released into the EBI for conveyance to the West Point Treatment Facility will be measured by the same magnetic meters.
- Untreated CSO discharges will be measured by the existing Denny Regulator Station. The regulator currently measures the overflows from the EBI, Denny local pipelines, and the Lake Union Tunnel.

6.8.3.2 Level Measurement. The following water levels will be measured, locally recorded, and telemetered to the West Point Treatment Facility as shown in Table 6-12:

- Wetwell water level for controlling the raw sewage pump operation.
- Pump Discharge Channel level for controlling the operation of the floatable material screens.
- EBI Control Structure water level above the weir for controlling the return flows to the EBI.

6.8.3.3 Gas Detection. A gas detection system will be provided to monitor the concentration of combustible gases and H_2S, LEL, and O_2 gas in the Wetwell and Drywell area.

6.8.3.4 Sampling and Monitoring. While the NPDES permit conditions are not finalized for this facility, the following are the proposed location and type of monitoring devices. Monitoring can be proposed for regulatory reasons, for process control reasons, or for information. The recommendations below include all of the above.

Influent samples are problematic because of the geometry of the project. Three influent streams join the tunnel at the east end, and two join the tunnel at the west end of the wet well. Flow measurement of the individual influent streams is not envisioned. Sampling at the Mercer Tunnel's East Portal or the Elliott West CSO Facility's wet well would be possible, but is not proposed at this time.

Flow Flow will be measured using flow measurement devices on the pump discharge pipelines. The following flows will be measured, recorded, and totalized.

- Flow to the Elliott Bay Interceptor.
- Flow to the Elliott West Outfall.

Flows out the Denny Way Outfall Extension will be estimated using the existing methods of weir measurement and calculation.

TSS, BOD, and settleable solids Tests for these constituents can be run on either a grab sample or a composited sample taken using a pump and refrigerated automatic sampler. No influent sampling for TSS, BOD or settleable solids is proposed. If influent sampling is required, a sampler could be placed in the wet well or the East Portal of the tunnel.

Effluent sampling is proposed at the Elliott West outfall discharge and the return flow to the Elliott Bay Interceptor (EBI). One sample will be taken in the CSO effluent channel and one in the Pump discharge channel. The sampler in the CSO effluent channel will be activated when the pumps run in CSO Treatment mode (pumping to the Elliott West outfall). The sampler in the pump discharge channel will be activated when the pumps run in the Tunnel dewatering mode (pumping to the EBI). The samples must be transported to West Point within the appropriate holding times.

pH Onsite test kits for pH will be provided. pH tests can be performed on grab samples.

Fecal coliform, pH and chlorine residual It is proposed to test for chlorine residual following dechlorination, to measure whether the dechlorination has been effective, rather than measuring the residual available prior to dechlorination. The sample will be taken at the Outfall transition structure, downstream of the dechlorination injection and mixing location. The sample would be pumped from the transition structure using a continuously operating sample pump. The sample for fecal coliform will be taken at the same location. A refrigerated automatic sampler could be utilized for the fecal coliform sample. The sampler would be located in the existing Denny Regulator structure and be operated when the pumps operate in the CSO Treatment mode.

The residual chlorine can be measured with a residual analyser that would operate continuously, and be regularly calibrated. The pH can be measured with a continuous analyzer. The analyzers would be located inside the existing Denny Regulator structure.

This pump or a second pump could also be used to sample upstream of the dechlorination facility to check the chlorine residual prior to dechlorination if sample tubing and valving are provided to allow pumping from either direction. This would be an option available for process control.

The signal from the Chlorine residual analyzer will be hardwired to the Elliott West Facility. The PLC will be programmed to shut down the hypochlorite feed pumps and provide an alarm in case the chlorine residual exceeds a certain setpoint for a defined period. This will provide a “fail safe” shut off to prevent release of chlorinated effluent to Elliott Bay.

Table 6-12
Level Sensors

Level Sensor	Type	Location	Controls	
L-1, 2	Bubbler	Wetwell	Effluent pumps on/off and speed Wetwell OCU on/off East Portal OCU on/off	Wa
L-3	Float	Pump Discharge Channel	Screens on/off CSO Treatment Structure OCU on/off	Wa
L-4	Bubbler	CSO Treatment discharge channel		Lev
L-5	Bubbler	Effluent discharge drop	Mixer on/off	Co t
L-6, L-7	Bubbler	EBI Diversion Structure upstream and downstream of weir	None	Wa
L-8	Bubbler	Denny Regulator	Tunnel Dewatering Mode on/off (Which controls Tunnel Dewatering Pumps, Wetwell Gate, and Pump Discharge Channel Gate) Lake Union Regulator Station Gate open/closed	Wa
L-9	Bubbler	Lake Union Regulator	None	Wa o
L-10	Float	Drywell sump	Sump pumps on/off and alarm	Op
L-11	Float	Wetwell sump	Tunnel Dewatering pumps off at low level, Trash pumps on/off, tunnel resets to Standby mode (Wetwell gate opens and Pump Effluent Gate closes)	Dev t
L-12	Bubbler	Denny Way Diversion Structure, upstream and downstream of both weirs	None	Wa
L-13	Bubbler	Central Trunk Diversion Structure, upstream and downstream of weirs	None	Flo f
L-14	Bubbler	City Manhole	None	Bac

6.9 Staffing Requirements

The Denny Way/Lake Union CSO Control facilities are intended to operate as unmanned facilities. However, the installed equipment and structures will need regular inspections and maintenance, and the overall facility will require housekeeping and supervisory tasks necessary for satisfactory performance. Equipment such as pumps must be exercised at least monthly to assure proper operation and readiness to operate. During a stormwater event, personnel should routinely inspect the facilities to ensure they are operating efficiently.

Operations and maintenance staffing requirements have been projected for operating King County's Denny Way/Lake Union CSO Control Project. Staffing requirements have been estimated for the following groups:

- *Supervisory*-Manages off-site facilities such as pumping stations, regulators, and disinfection facilities.
- *Operations*-Responsible for operation of the pumping stations, regulators, and disinfection facilities, including laboratory testing for process control and regulatory reporting.
- *Off-Site Facilities Maintenance*-Performs light preventative maintenance of equipment and upkeep of Elliott West grounds; performs periodic cleaning of Elliott West structures after CSO events; performs maintenance of Mercer Street Tunnel flushing gates; performs periodic inspections of facilities to report physical conditions; performs major repairs of tunnel, pipelines, equipment, and regulators.

An analysis of the staffing requirements of the Denny Way/Lake Union CSO control facilities was performed based on publications of the U.S. Environmental Protection Agency (EPA) titled "Estimating Staffing for Municipal Wastewater Treatment Facilities" and "Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities". This staffing estimate is intended as a guide for providing personnel and initial budget consideration for the facilities. Actual operating experience will determine actual manpower needs. The staffing analysis assumed that the Elliott West CSO Control Facility would discharge treated effluent intermittently. Ten discharges per year at a rate of 200 mgd was used. Table 6-13 lists the time breakdown requirements among the various staff positions, after adjustments for local conditions were factored, and estimates the needs of the CSO facilities.

Table 6-13
Operation and Maintenance Staffing

Personnel	Total Hours Per Year	Number of Full-time Equivalent Staff*
Supervisory	555	0.3
Operations		
Operations Staff	925	0.5
Laboratory Staff	185	0.1

Off-site Facilities Maintenance Maintenance Staff Yardwork Staff	 1,850 185	 1.0 0.1
TOTAL	3,700	2.0

*Assumes 1,850 hours per year per person

7. Mercer Street Tunnel- Basis of Design

This chapter describes the Mercer Street Tunnel and summarizes the predesign engineering work performed for the following tasks:

- Tunnel Design Criteria.
- Mercer Street Tunnel.
- East Tunnel Portal/Tunnel Drop Structure.
- West Tunnel Portal.

7.1 Mercer Street Tunnel Description

The Denny Way/Lake Union CSO Project includes construction of a tunnel to store 7.2 million gallons of CSO flow. The project includes the following elements:

- A 6,200-foot long, 14-foot 8-inch diameter tunnel extending beneath Mercer Street from Elliott Avenue West to near the intersection of 8th Avenue and Roy Street.
- A West Tunnel Portal excavation located adjacent to the Elliott West CSO Control Facility Site.
- A drop structure at the East Tunnel Portal near the intersection of 8th Avenue and Roy Street which would connect the Tunnel with the Lake Union CSO, South Lake Union CSO, and Central Trunk CSO pipelines.

The elements of the Mercer Street Tunnel project are described in more detail below.

7.1.1 Mercer Street Tunnel

7.1.1.1 Alignment. The tunnel alignment extends from the West Portal adjacent to the Elliott West CSO Control Facility Site, under Mercer Street from Elliott Avenue West to an East Portal to be located at 8th Avenue and Roy Street. The tunnel would have an inside diameter of 14 feet 8 inches and invert elevations of 83.0 (Metro Datum) at the East Tunnel Portal/Drop Structure and 75.0 at the West Tunnel Portal. No permanent forced air ventilation or lighting is being considered for the Tunnel.

The horizontal alignment of the Mercer Street Tunnel will proceed straight down West Mercer and Mercer Streets to near Dexter Street where it will curve toward the East Tunnel Portal/Drop Structure. This will mitigate the potential for settlement and distortion to the Seattle Center Mercer Street Garage but will require careful tunneling in the vicinity of the Broad Street Underpass, the properties on Dexter Street, and the inverted siphon underneath Dexter Street. The horizontal and vertical alignment of the tunnel are shown on the Preliminary Design Drawings.

The entire alignment is located within public right-of-way. The following permanent easements or rights-of-way would have to be obtained from the City of Seattle:

- Elliott Avenue West-from the Elliott West site to the east side of the street.

- West Mercer Street and Mercer Street-from the east side of Elliott Avenue West to 8th Avenue North.
- Mercer Street Tunnel Drop Structure- at 8th Avenue and Roy Street.

7.1.1.2 Tunnel Construction. A closed-face type boring machine may be required for Tunnel excavation. To maintain control of the ground in the tunnel heading and to mitigate the potential for settlement at the ground surface, an earth-pressure-balance machine may be required. Alternatively, an open-face digger shield in conjunction with dewatering or compressed air may be used.

A one-pass lining system will be required in the tunnel. Tight tolerances will be specified for the one-pass system to avoid poor grade control and eliminate irregularities in the precast tunnel liner. A cast-in-place concrete cunette used in conjunction with the one-pass lining should provide adequate grade correction if the tunnel is mined off grade. The tunnel lining will be designed and constructed to be relatively watertight.

7.1.1.3 Tunnel Flushing. A certain amount of solids deposition is expected to occur in the tunnel because of the minimal slope and the resulting low-water velocities, especially during tunnel emptying. The amount of deposition will depend on the characteristics of the wastewater, the amount of water stored, and the duration of the storage. Some scouring of sediments can be expected as the tunnel fills (because of the higher velocities); large amounts of materials will probably be carried out of the tunnel. However, the deposited materials would create a continuing odor problem that must be resolved. It is likely that wastewater would pond in portions of the tunnel as increasing amounts of sediment accumulate and add to the odor problem.

A low-flow channel (also known as a “cunette”) will be installed in the tunnel invert to concentrate the flow in a smaller channel, thereby increasing its velocity.

In addition to the cunette, a supplemental flushing water storage system will be provided for tunnel cleaning. The flushing water will be released in sufficient volume and flow rates to create scouring velocities. The most feasible source of flushing water is storage in the tunnel influent pipelines upstream from the tunnel in the Lake Union area.

To provide this flushing water storage a control gate will be installed at the East Portal/Tunnel Drop Structure. The gate could be manipulated to release water at an optimal rate for flushing the tunnel.

7.1.2 West Tunnel Portal

At the west end of the tunnel, the vertical alignment will be at invert elevation 75.0 (Metro Datum) to eliminate the Elliott Avenue undercrossing proposed in the Draft Facilities Plan. The West Portal location is shown in the Preliminary Design Drawings. With this revision to the vertical alignment, the West Tunnel Portal can be located on the Elliott West CSO Control Facility Site. This will mitigate the potentially adverse impacts on traffic, noise, vegetation, and settlement in the area east of Elliott Avenue West.

A 55 foot diameter construction shaft will be excavated at the West Tunnel Portal for tunnel machine access. It will also be used as an access/egress point for workers and rail cars (to transport tunnel excavation and support materials). The West Tunnel Portal excavation will be in conjunction with the excavation required for the construction of the Elliott West CSO Control Facility.

7.1.3 East Tunnel Portal/Drop Structure

7.1.3.1 Structure. The East Tunnel Portal/Drop Structure will be an underground, concrete structure that will be constructed in the excavation used for extracting the tunneling machine at Station 62 + 46.8. The East Tunnel Portal/Drop Structure will contain one spiral drop and a sluice gate, required to convey flow from influent pipelines to the tunnel. The East Tunnel Portal/Drop Structure will receive flows from the following pipelines:

- Central Trunk CSO.
- South Lake Union CSO.
- Lake Union CSO.

The East Tunnel Portal/Drop Structure will contain a permanent maintenance access shaft, an air shaft, and an odor control room. The access shaft will be covered with a concrete lift slab. Manhole access will also be provided.

The East Tunnel Portal/Drop Structure will be used to remove the tunnel boring machine after completion of the tunnel. The estimated depth of the structure excavation is 65 feet. The horizontal limits of the excavation to allow tunnel machine removal and construction of the structure are estimated to be about 55 feet in diameter.

7.1.3.2 Odor Control. The East Tunnel Portal/Drop Structure will require air to operate effectively. Air will escape from the tunnel whenever it fills with wastewater, and it is estimated that approximately 4,000 cfm of headspace air containing 1 ppm of H_2S will be vented through the structure. It is recommended that this air be treated to remove odor before it is released to the atmosphere. Space will be provided in the Mercer Street Tunnel Drop Structure for the odor control equipment. This space will be accessible from the street through a hatch and a concrete lift slab.

The means of odor control will be a passive activated carbon system. As the tunnel fills with water, headspace air must pass through the carbon media, so no forced ventilation is needed. A single 11-foot-diameter carbon unit will treat 4,000 cfm of air from the tunnel. The system will be designed with adequate space for a fan to be installed in the future, if desired. Because of the low H_2S content of the air and the intermittent operation, the carbon media will have a long service life.

Centaur carbon media will be used because it does not have the potential for combustion that caustic impregnated carbon has under intermittent operation. Although the initial costs of Centaur media are somewhat higher than those of caustic impregnated carbon, the Centaur carbon media can be regenerated with water when depleted. The media will meet the following criteria listed in Table 7-1.

Table 7-1
Carbon Media Design Criteria

Centaur Carbon Media	All Units
Iodine No., mg/g, min.	800
Ash, weight percent, max.	8
Moisture, weight percent, max.	2
Hardness Number, min.	95
Apparent Density, g/cc, min.	0.56
Mean Particle Diameter, mm, min.	3.7
H_2S Breakthrough Capacity, gH_2S/cc carbon	0.09

The carbon units will be single-bed, downflow units with foul air entering the top of the vessel and passing downward through the media. The vessels will be manufactured with filament-wound fiberglass-reinforced plastic (FRP). The exterior of the vessels will be resistant to ultraviolet degradation. The vessels will be capable of holding liquid to a depth sufficient to fully immerse the media for in-place regeneration of either water-regeneratable Centaur or caustic-impregnated carbon. The interior of the vessels will be resistant to both highly acidic and highly caustic solutions during the regeneration process and to continuous exposure to hydrogen sulfide gas.

The vessel will have two access hatches at the top for carbon replacement. Differential pressure meters will be provided across each carbon bed. Three sampling ports at one-foot spacing will be installed in the carbon bed. The ports will be used to sample the carbon media and to monitor gas concentrations during operation. Carbon vessel design criteria are shown in Table 7-2.

Table 7-2
Carbon Vessel Design Criteria

Carbon Vessels	East Tunnel Portal and Mercer Street Tunnel Drop Structure
Design airflow, cfm	4,000
Face Velocity, fpm	42
Number of Vessels	1
Vessel Diameter, ft	11
Carbon Bed Depth, ft	3
Pressure drop including inlet and outlet losses, in.	10
Sampling ports inner diameter, in.	2.5

7.1.3.3 Tunnel Flushing Gate A sluice gate will be installed at the East Tunnel Portal/Drop Structure to allow storage of water in the influent CSO pipelines: South Lake Union CSO pipeline and the Lake Union CSO pipeline. This gate could be manipulated to release water at an optimal rate for flushing the tunnel.

7.2 Design Criteria

7.2.1 Flow Conditions

The tunnel will be empty except when used for CSO storage. During most storms, CSO flows will be diverted through diversion structures and regulators into the tunnel. Approximately 50 times per year, CSO flows will be diverted into the east end of the tunnel from the south Lake Union area and into the west end from the Denny area. Tunnel flows will range up to more than 300 mgd. Storage amounts will range up to 7.2 million gallons.

7.2.2 Design Life Span

The tunnel will have a design life of 100 years. The portal structures will have a design life of 100 years. Mechanical equipment such as sluice gates and odor control units will have a design life of 20 years.

7.2.3 Materials

The proposed construction materials have been determined for the following major items.

- Tunnel Lining - One-pass precast segmental concrete lining with a cast-in-place concrete cunette in the invert.
- Tunnel Finish - Smoothly finished concrete.
- Tunnel Geometry - Circular with a cunette in the invert (Section 7.1.1.3).
- East Tunnel Portal/Drop Structure - Cast-in-place reinforced concrete.

7.2.4 Construction

The anticipated construction method and techniques for the tunnel and portals are as follows:

- Temporary Access Shafts - One each at the West and East Tunnel Portals.
- Type of Tunneling - Softground.
- Direction of Tunneling - West to east.
- Tunnel Boring Machine Removal - East Tunnel Portal/Drop Structure.
- Staging Area - West Tunnel Portal.
- Dewatering - West Tunnel Portal, and East Tunnel Portal/Drop Structure

7.2.5 Odor Control

An odor control system for the Mercer Street Tunnel will be located at the East Tunnel Portal/Drop Structure as described in Section 7.1.3.2, Odor Control.

7.2.6 Cleaning

The proposed tunnel-cleaning system will consist of a low flow channel (cunette) installed in the Tunnel invert and a flushing system using the storage capacity of the upstream CSO pipelines. The proposed system is described in Section 7.1.1.3, Tunnel Flushing.

7.2.7 Access

Permanent access will be provided at the East Tunnel Portal/Drop Structure and at the West Tunnel Portal located at the Elliott West CSO Control Facility Site.

7.2.8 Ventilation

No permanent ventilation system will be provided. A temporary ventilation system will be used when personnel enter the tunnel. The characteristics of that system will be addressed during final design and OSHA regulations.

7.2.9 Lighting

No permanent lighting system will be provided. A temporary lighting system will be used when personnel enter the tunnel.

7.2.10 Geotechnical

The subsurface conditions have been determined during the predesign through geotechnical explorations and are summarized in project specific geotechnical draft reports. Hazardous and contaminated materials encountered are defined in the geotechnical reports.

7.2.10.1 Predesign Subsurface Investigation Program. The Mercer Street Tunnel will be constructed primarily in overconsolidated, dense to hard glacial and interglacial soils. Near the portals of the tunnel, in the vicinity of the feeder lines at the south end of Lake Union, at the Elliott West CSO Control Facility, and at the Denny Outfall, recent normally consolidated, soft to loose soils overlie the glacially overconsolidated soils The complex soil stratigraphy along the tunnel alignment has been preliminarily defined by 21 borings obtained during two phases of subsurface exploration and by over 20 borings from other construction sites located within a city block on either side of the alignment. The borings were spaced about every 300 to 600 feet along the alignment.

7.3 Anticipated Subsurface Conditions

For tunnels, the most important factor is geology. The geology of the Mercer Street Tunnel is described below.

7.3.1 Geologic Setting

An understanding of the geologic history and the depositional processes which resulted in the soil stratigraphy in the project area is necessary to the understanding of the nature of the soils along the project alignment. This understanding is also necessary for anticipating subsurface conditions which may be expected based on past local experience with similar geologic units.

An interpretation of the geologic history of the downtown Seattle area has been used in the preliminary projection of probable construction-related soil behavior. The interpretations are based on information from borings drilled along the alignment, borings drilled for other projects in the vicinity of the alignment, and the geologic history of the Puget Sound area.

7.3.1.1 Regional Geology. Seattle is located in the central portion of the Puget Sound Lowland, an elongated topographic and structural depression bordered by the Cascade Mountains on the east and the Olympic Mountains on the west. The Lowland is characterized by low-rolling relief with some deeply cut ravines. In general, the ground elevation is within 500 feet of sea level.

The Puget Sound Lowland was filled to significant depths by glacial and non-glacial sediments during the Pleistocene Epoch; however, bedrock outcrops are scattered throughout the area. Within the city of Seattle, bedrock outcrops are found south of an east-west line extending from Bremerton to the middle of Mercer Island, which has been labeled the Seattle-Bremerton Fault, thought to be active within the last 1,000 years. Bedrock outcrops are present in only a few locations in the Seattle area: at Alki Point in West Seattle; the Duwamish Valley near Boeing Field; in the southern portion of Rainier Valley; and at Seward park in southeastern Seattle. Elsewhere the rock is deeply buried by Pleistocene and Recent sediments. Based on the results of deep drill holes and seismic profiling, the depth to bedrock in downtown Seattle is believed to be more than 3,000 feet.

Geologists generally agree that the Puget Sound area was subject to four major glaciations during the Pleistocene Epoch. Ice for these glacial events originated in the coastal mountains and the Vancouver Range of British Columbia. The maximum southward advance of the ice was about halfway between Olympia and Centralia. Ice thickness in the Seattle area may have exceeded one mile.

The Pleistocene stratigraphic record in the central portion of the Puget Lowland is a complex sequence of glacially derived and interglacial sediments. Erosion of certain deposits and local deposition of sediments further complicate the geologic setting.

7.3.1.2 Site Geology.

Based on the findings of explorations for the Mercer Street Tunnel alignment and on previous geologic interpretations for downtown Seattle soils, Table 7-3 presents a stratigraphic outline for the downtown Seattle late Pleistocene and Recent geologic history, beginning with the most recent deposits (youngest at the top and oldest at the bottom).

Table 7-3
Geological History

Period	Geologic Event
Post - Vashon (interglacial)	• Fill

	• Recent beach, alluvially reworked, landslide debris, and lacustrine sediments
Vashon (glacial)	• Glaciomarine drift • Glaciomarine deposits • Advance and/or recessional outwash
Olympia (interglacial)	• Not identified in project area
Pre-Vashon (glacial)	• Advance and/or recessional outwash

The oldest geologic unit encountered in the exploration programs was Pre-Vashon glacial outwash and/or recessional soils deposited as the glacial ice retreated northward and eastward out of the Puget Sound Lowland.

Subsequently, as glacial ice moved back into the Puget Sound region, glaciolacustrine clays and silts were deposited in a lake formed by the blockage of the Strait of Juan de Fuca. In some locations, these clays and silts were rhythmically laminated, representative of annual seasonal variations in ice melting and depositional rates. In other locations, the clays are massively deposited. Isolated lenses and layers of fine sand are fairly common. Near the glacial terminus, the ice may have been floating and, as it melted, it dropped coarse debris such as gravel, cobbles, and boulders into the clays and silts on the lake bottom. Icebergs floating in the lake dropped their debris load, and streams flowing out from the glacier carried granular material into the lake basin. Subsequent glacial overriding, consolidated these clays and silts into a hard, brittle material. Stress relief, associated with subsequent ice retreat and unloading, resulted in fracturing and fissuring, which significantly reduces the mass strength of these otherwise hard materials.

As the ice continued to advance, the sediments became coarser. Sediments classified as glaciomarine drift were deposited by several processes including streams flowing out of the terminus of the glacier, dropping of large quantities of iceberg-rafted sediments, and gravity flows at the outward edges of deltas into the lacustrine environment. Because of the multiple modes of deposition, this type of deposit is highly variable laterally as well as vertically. In general, the material is a mixture of coarser grained particles in a finer-grained matrix. In some areas, the glaciomarine drift resembles lodgment till. In the project area, these soils were subsequently overridden by glacial ice and may be virtually indistinguishable from lodgment till in both appearance and engineering properties.

Because of the waxing and waning of the glacial ice front and grounding and floating of the ice, glaciomarine drift and glaciolacustrine sediments are commonly interfingered. Both types of deposition occurred simultaneously in adjacent portions of the basin.

Advance of the ice closer to what is now Seattle resulted in the deposition of outwash sands and gravels in alluvial fan deposits and braided streambeds on the valley floor in front of the advancing grounded ice. The ice then retreated to the north and more glaciomarine and glaciolacustrine sediments were deposited.

The glacial ice retreated northward again, leaving a large lake in which a thick sequence of lacustrine silts and clays developed. Eventually the ice moved southward again for the last time.

In the 12,000 years since the last glacial episode, sediment has accumulated in low areas such as the Elliott Bay, the Lake Union area, and local lakes and swamps. In Elliott Bay, sands deposited by the Duwamish River and creeks from surrounding hills were interbedded with clays and silt during overbank floods. The clays were deposited in Elliott Bay and peat accumulated in swampy areas. The most recent sediments consist of fine sand, silt, and clay that were deposited in mudflats and near-shore environments, as evidenced by the numerous shell fragments they contain. Slope failures along the shoreline that is now Elliott Avenue left slope debris at the toe of the slope.

Within the last 100 years, extensive regrading has considerably altered the topography throughout the Seattle area. Substantial amounts of fill have been used to move the shoreline westward from the base of the bluff along the uphill side of Elliott Avenue. The railroad has moved westward on a series of timber trestles, remnants of which may still exist within the fill.

7.3.2 Descriptions of Geologic Units

The distribution of soils along the project alignment is illustrated in the Draft Geotechnical Reports. The strata have been delineated according to soil type. The geologic units and soil types along the project corridor are described below.

7.3.2.1 Advance and Recessional Outwash. This unit will be encountered in the eastern half of the tunnel. It is composed of granular soils which range from silty to clean fine sand and clean gravelly sand. In general, the unit is dense to very dense. Because of fluvial deposition of these soils, grain sizes can be expected to change over short distances both vertically and horizontally. These soils are generally water-bearing, but the amount of recharge will vary considerably. These soils may be connected directly to Lake Union, and are likely to flow into excavations if groundwater is not controlled.

7.3.2.2 Glaciomarine Drift. Glaciomarine drift occurs along the eastern quarter of the alignment. The composition of this unit is quite variable. It consists of clay, silt, sand, and gravel, any one of which can be the predominant grain size. In general, it is a mixture of coarse-grained particles in a fine-grained matrix. It is expected to vary radically by soil type over short distances. Local masses of sand, gravel, and cobbles, as well as boulders, can be expected, particularly at the top of the stratum, but also scattered throughout the unit. Cobbles and boulders up to 2 feet in diameter will be encountered frequently and boulders up to 6 to 10 feet across are likely to be encountered sparsely. The granular particles are hard, abrasive granitic or metamorphic materials.

Commonly interbedded within the glaciomarine unit are significant thicknesses of hard, gray, silty clay, and clayey silt. This clay-silt is often highly fractured and slickensided and has a blocky texture. It is similar in engineering properties to the glaciolacustrine soils, as discussed below.

Except for sand and gravel zones, the glaciomarine drift is relatively impervious and groundwater is frequently perched on top of it. However, the sand and gravel zones may yield significant volumes of water as experienced during construction of the Lake Union Tunnel where water-bearing sands flowed uncontrollably into the excavation. Excavation can be difficult because of the extremely compact and dense nature of the glaciomarine drift, which gives it a soft rock-like texture.

7.3.2.3 Glaciolacustrine Deposits. Glaciolacustrine deposits underlie much of the western half of the alignment. The glaciolacustrine unit consists of hard, gray, silty clay to clayey silt. It is predominantly highly plastic and with disturbance and exposure to water could become very sticky. Siliceous concentrations up to 6 inches across, cobbles and boulders ranging from 3 inches to 3 feet across, and occasional boulders as large as 10 feet across should be anticipated as evidenced by their presence in other downtown construction excavations.

The clays and silts range from massive to laminated and are frequently blocky or fractured. Locally they are distorted or sheared, having a lower mass strength than the surrounding soils. Slickensides, indicators of past earth movement, may also occur locally. Where open excavation or tunneling is carried out in this soil unit, the existence and orientation of pre-existing fractures and shear zones will control the stability of cut slopes as well as the stability of the tunnel heading and circumference of the tunnel.

7.3.2.4 Recent Deposits. Recent deposits in the downtown Seattle area generally consist of bay fill material along the shoreline to the uphill side of Elliott Avenue. These materials have not been overridden with glacial ice. Thus, they are generally loose to medium dense or very soft to stiff. While these materials will be encountered in the vicinity of Elliott Avenue and the Elliott West CSO Control Facility, they are not expected in the tunnel.

7.3.3 Seismicity

The Mercer Street Tunnel will be located in the Puget Sound Lowland which is a moderately active zone of seismicity. The largest earthquakes that have affected the region were two deep subcrustal events: the magnitude 7.1 Olympia Earthquake of 13 April 1949, and the magnitude 6.5 Seattle-Tacoma Earthquake of 29 April 1965. In addition to the deep subcrustal events, other seismogenic sources capable of producing large earthquakes, but not large earthquakes in historic times, include the Cascadia Subduction Zone (CSZ) off the coast of Washington, Oregon, northern California, and British Columbia (magnitude 8+), and shallow crustal block boundaries within the Puget Sound Lowland (magnitude 7 to 7.5).

Earthquake design ground motions specified by most building codes (UBC, AASHTO, API, AWWA) are either implicitly or explicitly based on ground motions that have about a 500-year recurrence interval. This criterion has been used for seismic design of other King County facilities (Renton Waste Water Treatment Plant, West Point Treatment Plant) and other lifeline facilities in the Puget Sound Region (Seattle Water Department Supply and Distribution Facilities). It would be reasonable to use the same criteria for design of the Mercer Street Tunnel. Recent regional probabilistic ground motion studies including deep subcrustal, CSZ, and shallow crustal block boundary events, indicate that a peak ground acceleration (PGA) of approximately 0.32g is consistent with a 500-year recurrence interval.

Earthquake-induced geologic hazards that may affect the site include ground motion amplification due to soft soils, liquefaction and related effects, fault-induced surface rupture, and landsliding. Ground motion amplification is not a significant hazard along the alignment as site specific ground motion studies conducted for other projects in the area with similar subsurface conditions indicate that little amplification or attenuation of the PGA would occur in the very dense or hard soils that underlie most of the alignment. Similarly, the very dense or cohesive nature of most of the soils along the alignment precludes liquefaction. The risk posed by fault-induced surface rupture is also relatively low. The nearest inferred fault to the site is the east-west trending Seattle Fault, located about 2 miles south of the alignment, which therefore poses little hazard of rupturing the ground surface at the site. In addition, it is likely that movement on this fault would be expressed in terms of a broad uplift occurring over thousands of feet, similar to the last large movement that occurred 1,100 years ago. Because this tectonic uplift would be experienced over a long distance, it is unlikely that movement of this fault would result in ground surface rupture in the vicinity of the Mercer Street Tunnel.

7.3.4 Geology Along Tunnel Alignment

From the West Portal, the tunnel will pass beneath landslide deposits and through disturbed glaciolacustrine soils consisting of fractured and slabby lacustrine clays. The upper quarter of the heading will also start out in saturated beach sands, potentially causing a flowing condition.

In the initial 50 to 100 feet, the tunnel excavation may encounter buried logs along the old shoreline and concentrations of boulders eroded out of the glacial soils that comprised the shoreline bluff. Water levels are anticipated to be 20 feet above tunnel crown and inflows will be concentrated along fracture planes. The clays are probably susceptible to swelling if left exposed and with the addition of free water. An expanded or grouted lining system will limit the introduction of water and resultant potential for swelling. Swelling can lead to a reduction in compressive and shear strength.

From Station 1+50 to 15+00, the Tunnel will pass out of the landslide-disturbed clays and into relatively intact lacustrine clays, which probably are locally fractured and blocky. Seepage should be negligible, except for minor seeps along sand seams or lenses.

Around Station 15+00, the Tunnel will pass into a mixed face condition with clay in the upper face and glaciomarine drift and outwash sand moving progressively upward into the tunnel from the invert. Boulders are likely to be concentrated along the weathered erosional surface between the overlying glaciolacustrine clays and underlying clayey to sandy glaciomarine drift.

By about Station 15+50, saturated outwash sand will occur in the tunnel invert. In the absence of position ground and/or water control, these sands will flow, resulting in unstable invert conditions. This could result in steering difficulties for the tunnel shield and poor bedding for the liner segments. In an unrestrained and undrained condition, groundwater inflows could be significant in these outwash sands, resulting in an estimated inflow of 5 to 15 gpm per 100 ft of tunnel length. The inflows are likely to be accompanied by a considerable quantity of flowing sand.

From Station 26+00 to 42+50, the tunnel will continue in a mixed face condition; however, the upper 10 to 20 feet of the outwash sand will be very fine-grained and silty, making it "livery" in tunneling terminology, and very difficult to drain or otherwise improve with grouting techniques. The livery soils will also make for a poor quality invert for shield advance and liner erection, as they will tend to flow into the tunnel when wet. The upper portion of the tunnel will be capped in glaciomarine drift and glaciolacustrine soils, resulting in a hard, resistant arch and upper face and a soft lower face and invert.

By about Station 42+50, the tunnel will have advanced from under the overlying layer of glaciomarine drift into a variable outwash/sandy till-like material that may not be able to mask ground losses around the advancing tunnel. Consequently, this reach may be much more susceptible to surface settlement than the preceding reaches. Boulders may be concentrated along the contact between the overlying glaciomarine drift and the underlying outwash. As with the previous reach, the tunnel face will be mostly in mixed soils, with flowing sand ranging from full face to invert level, and highly variable glaciomarine drift in the upper face and arch. While the outwash may be relatively amenable to drainage, the overlying layered and interfingered till-like/outwash material may be difficult to drain.

Along the extreme eastern end of this reach, as the tunnel curves along Broad Street, the face will be entirely in clean sand outwash with the groundwater level 20 to 30 feet above the tunnel crown. These soils will have a strong tendency to flow.

In summary, the entire alignment is overlain by a thick deposit of hard clay or till which is likely to bridge ground loss, resulting in negligible surface settlement. However, this does not preclude that appropriate mining equipment and techniques be specified to minimize potential ground losses. An earth-pressure-balance (EPB) tunnel boring machine (TBM) is appropriate for mining in these ground conditions. As an alternative to an EPB-TBM, it may also be possible to use an open-face TBM and compressed air tunneling methods, as discussed in more detail below.

In firm ground, the open-face TBM can advance rapidly and can more easily handle boulders or other obstructions (old piling near Elliott Avenue) than the EPB-TBM. However, in flowing ground, such as the outwash sand anticipated in the invert from station 15+00 to 25+00 and the "dirty outwash" deposit anticipated from station 45+00 to the East Tunnel Portal/Drop Structure and compressed air mining will have to be used in conjunction with the open-face TBM in order to minimize ground loss at the heading.

In isolated places, ground improvement methods such as chemical grouting, compaction grouting, and the like may be used to enhance the strength of the ground overlying the tunnel. Such methods will improve ground behavior and mitigate ground movement due to tunneling.

8. Outfall - Basis of Design

8.1 Outfall Description

The Denny Way/Lake Union CSO Control Project includes construction of two outfall pipelines to dispose of treated effluent and untreated CSO into Elliott Bay. Treated effluent will be discharged through the 96-inch Elliott West Outfall and untreated effluent will be discharged through a 120-inch diameter extension to the existing Denny Way CSO Outfall. Both outfalls will extend in a southwesterly direction from the existing Denny Way Outfall and Regulator.

The Elliott West Outfall will discharge effluent which has been screened; chlorinated, to reduce the fecal coliform count to 400 colonies, or less, per 100 ml; and dechlorinated, to meet Class A marine water quality standards for residual chlorine. The elevation of the discharge will be approximately -60.0 (MLLW Datum). The Elliott West Outfall will be a 96-inch pipeline with a duckbill tide valve at its extreme end.

Untreated effluent will be discharged through an extension to the existing Denny Way CSO Outfall (a new 120-inch diameter pipe). The Denny Way CSO Outfall Extension will extend the discharge depth so that the crown of the 120-inch diameter outfall pipe will be below MLLW. This depth will ensure that the pipe and associated protection will remain below the seabed and the Discharge Structure will be below the surface of Elliott Bay during the lowest tide. The Denny Way Outfall currently discharges onto the foreshore at Elliott Bay just below mean tide level.

The Outfalls will have the following components:

- Dechlorination injection structure for the Elliott West Outfall only.
- Transition structure and onshore pipelines.
- Inshore outfall portion extending to a water depth of 20 feet (MLLW).
- Offshore portion of the Elliott West Outfall extending from an elevation of -20.0 to -60.0 (MLLW).

8.1.1 Dechlorination Injection Structure

The Dechlorination Injection Structure for mixing sodium bisulfite into the treated effluent will be constructed upstream from the Elliott West CSO Control Facility Outfall. The injection structure is shown on the Design Drawings. The injection structure will receive sodium bisulfite through a 2-inch pipeline from the Elliott West CSO treatment plant. A diffuser and mixer will be used at the Injection Structure to mix the sodium bisulfite into the outfall pipe. Chlorine residual monitoring instruments downstream from the injection point in the Transition Structure will provide information for adjusting the sodium bisulfite dosage.

8.1.2 Transition Structure

8.1.2.1 Location. The new Transition Structure will be south of the existing Denny Way Discharge Structure. A preliminary layout of the Transition Structure and associated pipelines is presented in the Preliminary Design Drawings. The alignment of the longitudinal axis of the structure will be approximately south 60 west. The structure will be about 30 feet long (about 18 feet of which would be visible at the surface) by 31 feet wide. The location will greatly facilitate construction since the Transition Structure will be clear of the existing Denny Way Outfall structure.

8.1.2.2 Onshore Pipelines. The only known potential obstructions to the onshore construction activities are the pile supported 96- and 72-inch pipelines which will be crossed by the 96-inch Elliott West Outfall pipeline at its approach to the new Transition Structure. However, the existing pipelines could be connected to the new Denny Way CSO Outfall and the redundant lengths demolished before the new 96-inch pipeline is constructed. The existing 96-inch EBI overflow pipeline will have to be realigned to intersect the Transition Structure. This will necessitate the construction of a thrust block, probably to be supported on piles.

Since the existing 96- and 72-inch pipelines must remain in operation during the construction of the shoreline facilities, it may be necessary to temporarily divert one or both pipelines and to provide a discharge into Elliott Bay. With the Transition Structure in the proposed location, the need for a temporary diversion is less likely.

8.1.2.3 Transition Structure. The Transition Structure will be constructed of reinforced concrete using a cofferdam. The existing Denny Way Discharge Structure is equipped with a flap gate on the 96-inch pipe. A flap gate is proposed on the Denny Way CSO Outfall Extension at the Transition Structure to prevent backflow into the EBI during high tide. No flap gate will be required on the Elliott West Effluent pipeline. Stoplogs will be provided to both pipelines to enable inspection and maintenance of the flap gate and upstream pipelines. The proposed configuration of the structure is depicted in the Design Drawings.

The existing flap gate on the Denny Way Discharge Structure is a fabricated steel assembly, hinged at the top. During flow, the stiffened steel plate cover is forced open. During periods of little or no flow, the flap gate is closed to prevent an inflow from rising tide and surge. A mating steel ring in the back of the Discharge Structure serves as a seal between the cover and the opening. It may be possible to salvage portions of the flap gate when the existing Denny Way Discharge Structure is demolished.

Alternative materials will be investigated for the fabrication of a new flap gate at the Transition Structure. In addition to steel and cast iron utilized in the existing structure, materials with different weight and resistance to corrosion such as plastics and fiberglass will be considered.

The Transition Structure will be designed to blend into the surroundings and to facilitate access for maintenance; the top of the structure will be at about the same elevation as the existing park (approximately 16.0 (MLLW)). The exposed top of the Transition Structure will be made less visible by landscaping and artwork. The offshore edge of the structure will be protected with riprap.

8.1.2.4 Foundation Support. The subsurface soil profile near the proposed Transition Structure appears to consist of 20 to 25 feet of mixed fill soils on top of 10 to 15 feet of marine silty sands to clean sands, with shell fragments overlying dense or hard glacial tills. The fill may be a mixture of silt, sand, and gravel with some fragments of wood, brick, concrete, and glass. Based on penetration resistance values (blow counts), the fill is medium dense to dense, with occasional loose or soft zones.

The Standard Penetration Test (SPT) results indicate competent soil adequate for supporting the outfall pipe at an elevation of approximately -25.0 to -30.0 (MLLW). SPT values of 30 or greater are considered adequate to support structures depending on their configuration. It is likely that the Transition Structure will have to be supported on piling.

8.1.2.5 Cofferdam Construction. It is expected that the Transition Structure and the on-land pipelines entering the structure will be constructed in the dry using a cofferdam. A cofferdam is a temporary structure designed to keep water and soil out of the excavation in which a structure is to be built. Cofferdams are commonly used in the construction of bridge piers, dams on inland waterways and waterfront structures such as that required at Denny Way. Usually cofferdams are dewatered, in whole or in part, so that the structures may be built substantially in the dry.

The cofferdam will be designed by the construction contractor and will consist of a closed box on four sides. Sheet piling will be driven around the perimeter of the structure to be built. The cofferdam will be designed to resist water pressure and soil using internal bracing or by cantilever action of the sheet piles. Bracing systems typically consist of horizontal wales and struts at as many levels as necessary to resist the external forces. The enclosed area will be approximately 50 feet by 60 feet. The southern leg will be driven into the embankment above the highest expected high tide (approximately 15.0 MLLW). Penetration of the sheet piles may be up to 35 feet to 40 feet below the bottom of the excavation.

In conjunction with the sheet-piled cofferdam at the shoreline, a braced excavation sized about 1,400 square feet will be used onshore from the Transition Structure for working on the on-land pipelines. Temporary support will be provided for existing facilities that are not already on piles.

Following construction of the Transition Structure, the sheet piles would be pulled or cut off well below the seabed and the top portion retrieved.

8.1.3 Inshore Outfall Portion

The inshore outfall, which extends approximately 150 feet from the Transition Structure to an elevation of approximately -20.0 (MLLW) comprises the entire Denny Way CSO Outfall Extension and Discharge Structure, and a portion of the new Elliott West Outfall.

The Denny Way CSO Outfall Extension consists of approximately 120 feet of 120-inch pipe and a Discharge Structure. The extension will move the discharge point approximately 150 feet offshore from its current location, so that the Outfall will remain submerged under all tidal conditions. The Outfall will be oriented to the southwest.

Adjacent and parallel to the Denny Way Extension is the 96-inch Elliott West Outfall, which extends a further 360 feet before terminating in a Discharge Structure.

Both the 96-and 120-inch outfall pipes enter the Denny Way Discharge Structure at an elevation of approximately -20.0 (MLLW). The 120-inch pipe terminates at the structure; the 96-inch pipe passes through and continues offshore.

8.1.3.1 Outfall Pipes. The 120-inch Denny Way CSO Extension and the 96-inch Elliott West Outfall pipes will be installed in a sheet piled trench on a series of pile supports as shown on the Preliminary Design Drawings. The pile supports consist of a precast reinforced concrete cradle and pile cap supported on three driven piles embedded in the glacial till. Pile support spacing is dependent on pipe configuration. Utilizing standard pipe segments would require pile bents at every 12 to 24 feet; the spacing will vary depending on alignment. The practical lift load capacities of the trestle-mounted crane and the lengths of pipe that can be delivered by truck may also restrict pipe sizes. The pile support elevations along the alignment of the Outfall would vary to maintain at least 5 feet of clearance between the top of pipe and the seabed for backfill while maintaining an adequate slope on the pipeline.

After driving the sheet piles, the trench would be excavated to a depth of approximately 15 feet, followed by the installation of pairs of support piles. The piles would be fabricated from either steel or precast reinforced concrete depending on depth and diameter required. Steel 'H' section piles can be driven the most easily into the glacial tills, as they develop little of their capacity by end bearing which gives them good lateral resistance during earthquakes. The 'H' piles have a major and a minor axis, so they have different properties depending on the direction of any externally applied force. They are also difficult to align when driving without a very rigid temporary driving 'gate'.

Tubular, or pipe, piles have the same properties irrespective of the direction of the applied force; alignment is therefore not a major problem. If tubular piles are driven open-ended, penetration of the pile into glacial tills is usually limited to about 10 feet. If driven close-ended, very high resistance can be achieved for vertical load bearing, with only minimal penetration. This does not provide good resistance to lateral loading during earthquakes. Precast concrete piles have characteristics similar to close-ended tubular piles, but the required length of each pile has to be determined before driving.

For this project, the optimum pile type will probably be an open-ended tubular pile to provide both vertical and horizontal capacity. This configuration is similar to the one used for the West Point CSO outfall, although the original design had specified closed-ended tubular piles.

The principal construction activities associated with the inshore outfall portion are:

- Constructing a steel trestle from shoreline to approximately 150 feet offshore.
- Driving sheet piles at about 35 feet lateral spacing along the Outfall to form the trench.
- Excavating sediments to a minimum depth of 15 feet below natural seabed. Contaminated dredge spoil will be removed by barges for disposal onshore or at an offshore dump.

- Driving three support piles for each bent into the trench bottom at a spacing of between 12 and 24 feet.
- Installing pile caps.
- Placing and joining pipe segments into pipe cradle.
- Extracting or cutting back the sheet piles to the seabed.
- Placing backfill over the pipe.
- Removing the trestle.

The trestle will not be a contract requirement, but is anticipated to be the contractor's preferred method for outfall construction and its design will be the contractor's responsibility. The trestle will probably be constructed from bolted steel sections and be a temporary construction. The trestle will require interface with construction of the shoreline Transition Structure and will also require access roads, ramps, and turning bays for trucks and construction equipment. To provide a stable platform for cranes, the trestle should be braced in the transverse and longitudinal directions and should be approximately 40 to 50 feet wide.

The pipeline trench may be located in the interior bay of the trestle. Trench excavation will be done with clamshell equipment deployed from the trestle. The trestle will support construction equipment such as power packs, compressors and ancillary equipment for diving, pile driving, jetting and rocking operations. After driving of sheet piles along the length of the trestle, the trench will be excavated to grade for 40 to 50 feet. Piles would then be driven through a template supported from the trestle into the bottom of the trench and cut off to the predetermined level. Pile cap structures will be lowered from the gantry crane to the top of the piles. The pile cap/pile sleeve will be grouted to secure the bent. The pipes will be lowered into the trench supported from the pipe cradles. The pipe segments will have to be jointed underwater using a special connection system (hydraulic horse). Pipe will be installed in sections and backfilled with rock as each section is completed.

8.1.3.2 Denny Way CSO Outfall Extension Discharge Structure. Both the 96- and 120-inch outfall pipes enter the Denny Way Discharge Structure at an elevation of approximately -20.0 (MLLW). The 120-inch pipe terminates at the structure; the 96-inch outfall pipe passes through the structure and continues offshore. The Denny Way Discharge Structure will be constructed of reinforced concrete. The configuration of the proposed structure is shown on the Preliminary Design Drawings.

The Denny Way Discharge Structure will be located approximately 130 feet from the shoreline and will discharge CSO flows into Elliott Bay. The structure will also serve as the take off point for the offshore section of the 96-inch Elliott West Outfall, which extends an additional 360 feet offshore. The structure will be of substantial size to accommodate the large diameter pipelines.

The structure will weigh approximately 250 to 300 tons and will be supported on a pile foundation. The unit will be cast on a flat-top barge and will be floated to the site for installation using a barge-mounted crane. The trestle will extend close to the Discharge Structure and be utilized for rigging and alignment. The Discharge Structure will be placed following excavation of the trench from the trestle; then the 96 and 120-inch diameter pipes will be back-laid to the Transition Structure outlet, with backfill placed as the installation progresses.

A scour apron will be placed seaward of the Discharge Structure to protect the sediment cap from scouring by the high-velocity discharge. The apron would be constructed of concrete, as an integral part of the structure.

The end of the outfall should be protected with a one-way valve to keep out sediments, saltwater, and marine creatures; however, since the Denny Way Extension has no available hydraulic head to operate a valve of the required size, a valve will not be installed. Therefore, the outfall must be periodically inspected and cleaned.

8.1.4 Offshore Outfall Portion

The offshore Outfall extends approximately 360 feet from the Denny Way Discharge Structure to an elevation of -60.0 MLLW and comprises the remaining portion of the 96-inch Elliott West Outfall. Because of limited water depth, floating equipment cannot be used in the inshore outfall region. The offshore Outfall will be located in deeper water and therefore could be constructed using floating equipment.

8.1.4.1 Outfall Pipe. The offshore outfall pipeline will be constructed on piles similar to the inshore portion. However, the pipe will lie approximately at the sea floor with the bottom of the pipe at the mudline or partially buried. Depending on side slope and pipe protection requirements, the outfall could be partially buried up to the springline (mid-depth) of the pipe. Articulating concrete mattresses, supported y the pipeline but extending to the seabed on each side of the pie, will be placed over the outfall for pipe protection and enhancement of marine habitat. A cross section of 96-inch diameter Elliott West Outfall pipe, with concrete mattresses and pile supports, is shown on Figure 2-4.

The pile supports consist of a precast reinforced concrete cradle and pile cap supported on a pair of open-end steel piles driven into the glacial tills. Depending on the type of pipe used, the pile spacing could vary between 12 and 60 feet, at the option of the Contractor. The outfall design, as shown on the drawings, is based on a pile spacing of 24 feet.

Use of monolithic pipe sections for the offshore section of Outfall is made possible by the ability to use floating lifting equipment in the deeper waters and/or by floating the pipe sections to the site. Long pipe sections are advantageous as the number of joints is reduced, which reduces the duration of the marine construction work. Longer sections require a different method of connection than the typically used bell and spigot connection.

The principal construction activities associated with this concept are:

- Excavating bottom sediments at pipe support locations to the bottom of the pile cap.
- Driving a pair of support piles into the trench bottom at the appropriate pile spacing.
- Installing pile caps or pile support/clamps depending on the type of pipe used.
- Placing and joining pipe segments into pipe cradle.
- Backfilling the excavated area with clean sand to the original sediment elevation.

Modified pipe supports which incorporate a clamping assembly may be utilized. Following driving of the support piles and installation of the pile support/clamp assembly, the long pipe section will be either floated or delivered to the site by barge and ballasted into the saddle supports, or lowered by floating crane into the saddle supports. An upper clamp will then be fastened over the saddle section providing a permanently grouted seal. Pile supports can be designed with stab-in guides and guide wires to provide directional control during placement of the neutrally buoyant pipe. Alternatively, the standard bell-and-spigot technique could be used from a floating crane with a hydraulic horse mechanism.

Excavation and installation ofthe pile supports may be done concurrently with trestle construction and inshore trenching. Offshore installation would require the use of a floating crane fitted with dredging and backfilling equipment and a grouting station. A support/supply vessel will be required on site on a full-time basis during the offshore construction to transport construction personnel and materials to and from the construction platform. Supply barges will be used to excavated material and backfill.

8.1.4.2 Elliott West Outfall Discharge Structure. The Elliott West Outfall Discharge Structure will be located approximately490 feet from the shoreline at an elevation of about -60.0 (MLLW). It will discharge treated effluent intermittently; on the average of 8 to 12 times per year.

The outfall will be sloped toward the discharge point throughout its length, closely following the slope of the sediment cap. At the Discharge Structure, the outfall will be reduced to 90-inch diameter and will discharge horizontally through a 90-inch duckbill check valve.

The Discharge Structure for the Elliott West Outfall will be precast in reinforced concrete and lowered to the seabed using a floating crane. The 75- to 100-ton structure will be supported on a number of driven piles, probably open-ended steel tubes.

8.2 Outfall Effluent Characteristics

8.2.1 Existing CSO Effluent Quality

CSO samples from three locations at the existing Denny Way Regulator were collected during four overflow events from December 1996 to March 1997. Concentrations of total suspended solids (TSS) and settleable solids were collected at the Denny/Lake Union Regulator at the weir and the gate. TSS concentrations at each location ranged from 69.5 to 117 mg/L and averaged approximately 91 mg/L, indicating that the flow in the Tunnel is well mixed. Settleable solids ranged from 41.5 to 66.2 mg/L and averaged 55 mg/L.

Total coliform counts ranged between 1.5 million and 5 million MPN/100 ml, and averaged 2.6 million MPN/100 ml. Metals analyses revealed that concentrations of eight of the nine metals tested for were below the acute limits. However copper concentrations exceeded the acute criteria by a factor of 5 to 9.

8.2.2 Design Flows

The design flows for each project component have been derived from the hydraulic analyses of design storms or from the 6-year continuous simulation performed by King County. These peak design flows, presented in Table 8-1, were set to ensure sufficient capacity to meet the overall project goal for once-per-year CSO control, or to provide adequate hydraulic capacity for system discharge. For the Outfalls, the value is the maximum from the analysis of extreme conditions. The peak design flows through the Outfalls during worst case conditions are 300 mgd for the Elliott West Outfall and 375 mgd for the Denny Way Extension. The once-per-year storm event flow through the Elliott West Outfall (based on Design Storm 6) will be 250 mgd. The hydraulic profile for the overall project is indicated on the Preliminary Design Drawings.

Table 8-1
Outfall Design Flows, mgd

Elliott West Outfall	Denny Way CSO Extension Outfall
300	375

8.2.2.1 Available Head for Gravity Discharge. The hydraulic profile on the Preliminary Design Drawings shows that the maximum water surface elevation in the Elliott West CSO Control Facility Mixing Chamber (the beginning of the Elliott West Effluent Pipeline) as 134.32 (Metro datum). The elevation of mean higher high water (MHHW) is 105.25 (Metro datum). Therefore, there is an available head of approximately 29 feet (excluding losses) for the Elliott West Outfall at MHHW.

At the Denny Way CSO Outfall Extension, the hydraulic profile shows an addition of 8 inches to the weir from the Elliott Bay Interceptor (EBI) to the Outfall. The elevation of the weir will be 102.2 (Metro datum), providing an available head that is dependent on the stage of the tide. A flap gate prevents seawater from flowing into the EBI during high tide. The ground surface and therefore the maximum possible water level without discharging through the manholes is 111 (Metro datum). Therefore, the available head for gravity discharge is approximately 6 feet at MHHW.

8.2.2.2 Effluent Density. According the *Monitoring Report (1997)* by Herrera Environmental Consultants, total solids concentrations in wastewater at the existing Denny Regulator Station at the Lake Union Gate range from 150 mg to 1100 mg with an average of 550 mg. [The Report used the units mg not mg/L, which are the standard reporting units for Total Solids by SM2340G that Herrera used.] Based upon this value, assuming the volume of solids is negligible when compared to the volume of water, and using a fresh water density of 0.99973 g/cm^3 at 10^{o}C, the average density of CSO effluent is 1.0003 g/cm^3.

8.2.2.3 Scouring Protection.

Based on the design flows described, the maximum estimated outfall velocities are 9.2 feet per second (fps) from the 96-inch Elliott West Outfall through a 90 inch duckbill tide valve and 7.3 fps from the 120-inch Denny Way CSO Outfall Extension.

Considering these pipe exit velocities, concrete scour aprons will be needed to prevent movement of the bottom sediments at both the Elliott West Outfall and the Denny Way CSO Outfall Extension Discharge Structures.

8.2.3 Elliott Bay Characteristics

The receiving waters of Elliott Bay within Puget Sound have the following characteristics.

8.2.3.1 Tidal Levels.

Tides within Puget Sound are strongly diurnal with one tide per day dominant. The tidal characteristics are given in Table 8-2.

Table 8-2
Tidal Parameters

Tidal Event	Metro Datum (Feet)	MLLW Datum (Feet)
Highest recorded tide	108.55	14.65
Annual maximum (HAT)	107.10	13.20
Mean higher high water (MHHW)	105.25	11.35
Mean high water (MHW)	104.39	10.49
Mean tide level (MTL)	100.56	6.66
NGVD 29	100.00	6.10
Mean low water (MLW)	96.73	2.83
Mean lower low water (MLLW)	93.90	0.00
Annual minimum (LAT)	91.30	-2.60
Lowest recorded tide	89.00	-4.90

8.2.3.2 Currents.

In general, the flood tide enters Puget Sound from the north and generates clockwise currents in Elliott Bay. On the ebb, however, a series of gyres are formed; some clockwise and others counterclockwise.

A conceptual model of the water currents in Elliott Bay, developed by Evans-Hamilton, Inc., shows that the fresh water entering the bay from the Duwamish River flows in a surface layer up to 10 meters deep northwards along the waterfront, irrespective of the state of the tide. North of Pier 70 the Duwamish discharge is parallel to the shore, heading past the net pens and grain terminal before turning west at Piers 90 and 91 past the Elliott Bay Marina. The fresh water plume can be identified as far north as West Point before being dispersed by the flood tidal eddy immediately south of West Point. The net current vectors indicate that at the site of the proposed Outfalls, flow is parallel to the shore.

The surface current is dominated by the outflow from the Duwamish River, with a saline counterflow in the lower part of the water column. During low flow in the

Duwamish River, a salt wedge has been detected up to 10 miles upstream from Elliott Bay.

8.2.3.3 Winds.

Wind data collected at West Point was obtained in summary tables which present the number of hours per month for the period between 1974 and 1988 (except 1982 and 1983) when winds exceeded 30 mph, the annual maximum observed 2-minute average wind speed, and the average 2-minute wind speed for various return periods (CH2M Hill 1995). The data is generally divided into two sectors: the north sector (WNW to NE) and the south sector (SSE to WSW). In the summer, winds are often light from the north; in winter the winds are much stronger and blow predominantly from the south and southwest. Maximum 2-minute average wind speeds at West Point from the north sector ranged from 22 mph, from 338°, to 42 mph, from 346°, averaging 29 mph, from 353°. From the south sector, the maximum 2-minute average ranged from 35 mph, from 190°, to 50 mph, from 181°, averaging 39 mph, from 190°. The Oceanographic Data prepared by Evans-Hamilton includes wind data collected during March 14 - June 26, 1996. During this period, the wind never exceeded 10 m/s (approximately 22 mph).

8.2.3.4 Waves.

The above information is not representative of winds that will be generating the waves; however, using the mean of the maximum 2-minute average wind will yield a conservative definition of the maximum waves that could be expected.

NOAA charts and USGS maps indicate that the greatest fetch from the southeast is approximately 2 miles, and from the southwest is approximately 8 miles (from 235°-240°). Winds from a more southerly direction than 230° are blocked by Alki Point. Winds from the north tend to follow Magnolia Bluff around into Elliott Bay which creates a maximum fetch of approximately 5 miles (personal communication with Captain Ken Lilly (ret), CH2M Hill).

Based upon above wind information and on Figure 3-24 of the *Shore Protection Manual* (USACE 1984), a wave of about 3.4 feet would be generated by winds of 39 mph blowing over an 8-mile fetch from the southwest for a period of 1.9 hours. The wave period would be approximately 3.8 seconds.

Winds from the north sector would generate a wave of about 1.9 feet when blowing at 29 mph over a 5-mile fetch from the north for a duration of 1.5 hours. The wave period would be approximately 3.0 seconds.

Shipwash may be the biggest source of waves since it can generate waves of up to 4 to 5 feet at the shore. For final design, a significant wave height of 4 feet with an associated period of 4.0 seconds will be used.

8.2.3.5 Seawater Density.

During the data collection in 1996, salinity profiles were collected at several sites in Elliott Bay. At Site 2, the closest site to the outfall location, six salinity profiles were measured between 18 March and 18 June. The results are shown in Table 8-3. Evans-Hamilton reports that the near-surface (0 to 3 meter) density in the vicinity of the Denny

Way Outfall ranges seasonally from a sigma-t of 19.5 to approximately 21 (1.0195 to 1.021 g/cm^3). The variations are most probably caused by changes in flow from the Duwamish River. In the mid-depth layer, deeper than 8 meters, the sigma-t ranges only from 21.5 to 22.5 (1.0215 to 1.0225 g/cm^3).

Table 8-3
Salinity Profile

Depth (Feet)	Salinity Profile (parts per thousand)					
	18Mar	17Apr	6May	20May	4June	18June
5	19.9	19.6	20.0	18.3	19.8	20.4
10	20.4	19.9	21.5	18.5	20.6	21.1
15	20.7	20.2	21.7	20.3	20.8	21.3
20	20.8	21.3	21.9	21.4	21.0	21.4
25	20.8	21.6	21.9	21.6	21.2	21.5
30	21.3	21.7	22.0	21.7	21.3	21.5
35	21.5	21.7	22.0	21.7	21.5	21.5
40	21.5	21.8	22.0	21.8	21.6	21.6
45	21.5	21.8	22.1	21.8	21.7	21.6
50	21.5	21.8	22.1	21.8	21.8	21.7
55	21.5	21.9	22.2	21.8	21.8	21.8
60		21.9	22.2	21.8	21.8	

8.3 Mapping and Geotechnical Design Basis

8.3.1 Topography

An aerial survey of the onshore portion of the site was conducted in June 1997. The topographic mapping has been prepared as a separate AutoCAD base layer.

8.3.2 Bathymetry

A bathymetric survey of the marine portion of the site in July 1997 covered an area approximately 1,200 feet long (600 feet on either side of the proposed outfall location) by 600 feet offshore and to an elevation of approximately -88 (MLLW). The topographic and bathymetric surveys have been combined into a single AutoCAD base layer. The final sub-bottom profile and magnetometer surveys have also been put on AutoCAD layers.

8.3.3 Seabed Sediments

Geologic profile, strata, and cross-sections have been created based upon the draft geotechnical boring logs and are shown on the Preliminary Design Drawings. The logs will be finalized when information of grain size and water content is available.

In order to limit settlement of the Outfalls, a minimum SPT count of 25 blows per foot in cohesive soils or 75 blows per foot in granular soils is required to install the outfall pipe directly on the seabed sediments.

It is expected that the lateral forces generated during an earthquake will be the controlling factor for pile stability. The anticipated earth acceleration during an earthquake of 7.5 on the Richter Scale is 0.32g , or between 4 and 6 inches of movement, depending upon the soil type. The upper soils above the glacial tills are all silts and silty sands.

Ten feet of penetration into the glacial tills is considered sufficient for piles to support the outfalls, assuming 24-inch diameter open-ended steel tubular piles at a spacing between 12 and 15 feet.

The existing slopes which vary from 4H:1V inshore to 12H:1V are indicative of the long-term angle of repose for the soft surficial sediments. A maximum short term slope stability of 6H:1V is anticipated, as this was the short-term stability at a project located south of the site in Elliott Bay with similar soft sediments.

Dewatering of some of the very soft sediments may be a problem. According to *Elliott Bay Waterfront Recontamination Report* (EBDRP 1995) prepared for the Elliott Bay/Duwamish Restoration Program, the sedimentation rate (net sedimentation less resuspension) ranged from 0.3 to 1.8 g/cm^2/yr and averaged 0.8 $\pm$ 0.17 g/cm^2/yr. At the sampling station located near the Seattle Aquarium (the closest station to the site) the sedimentation rate ranged from 0.4 to 0.8 g/cm^2/yr and averaged 0.55 g/cm^2/yr. The accumulation rate associated with this sedimentation rate ranges from 0.6 cm/yr to 1.7 cm/yr, averaging 1.1 cm/yr. The net accretion rates for all the sites studied ranged from almost zero to nearly 4 cm/yr (1.6 inch/yr). For this project, a net accretion rate of 1.0 cm/yr has been assumed.

It is unlikely that the offshore soils excavated as part of the construction will be suitable for use as backfill. Some material from farther inshore may be suitable. It is expected that a large proportion of the backfill will have to be imported.

8.4 Pipe Design Parameters

8.4.1 Outfall Dilution Modeling

Plume modeling was conducted using the UM component of the EPA plume model PLUMES. The input data includes outfall configuration, effluent characteristics, and receiving water characteristics. Important outfall criteria include depth of water over the discharge point, angle of discharge, and size and shape of the exit port. Important effluent characteristics include density and flow rates. Important receiving water characteristics include density profile and currents.

The model was run for five flow rates and two current profiles. Results are summarized in Table 8-4. The dilutions shown are calculated at the edge of the chronic mixing zone which would be 80 m (260 feet) from the Outfall. The current profiles used represent the 90 percentile currents and the mean current speeds. For this outfall configuration, higher speeds result in lower dilutions. At lower speeds, the plume has more time to mix before it reaches the edge of the mixing zone. At the highest anticipated discharge rate of 300 mgd, expected dilutions would be 9 or higher.

For the range of conditions expected, the model results were most sensitive to changes in current speeds. The 90 percentile currents can be used to represent a worst case condition for currents. More typical currents such as those represented by the mean current speeds result in dilutions that are approximately 25 to 50 percent higher in the flow ranges of 250 mgd to 300 mgd. Variations in the expected range of effluent density and receiving water density profile produced only minor changes in predicted dilution.

Table 8-4
Summary of Predicted Outfall Dilutions

Velocity Profile	50 mgd	100 mgd	200 mgd	250 mgd	300 mgd
90 Percentile Currents	12	9	8	7.3	7.2
Mean Current Speeds	18	13	10	9.6	9.3

8.4.2 Concrete Pipe

The outfalls will be constructed of concrete pipe with steel joints, of flush bell design, with single rubber O-ring gaskets. The nominal wall thickness will be 9 inches for the 96-inch pipe and 11 inches for the 120-inch pipe. The steel cylinder design (AWWA C300) will be used. The weight per foot is 3,510 lb/ft for the 96-inch pipe and 5,350 lb/ft for the 120-inch pipe.

Thrust tie rods will be used for joint restraint in the marine portion of the Outfalls. The pipe lengths are assumed to be 24 feet.

8.4.3 Pipe Cover

The depth of minimum cover over the marine outfall pipe is as shown on the Preliminary Design Drawings. The inshore portion of the Outfalls will have a cover of 5 feet of gravel backfill with minimum specific gravity of 2.65. A thin layer of sand cover may be placed over the backfill material to provide a substrate similar to what currently exists, or the gravel cover may be left exposed.

The offshore portion of the Outfall will rest on piles with the bottom of the pipe just above the existing seabed. Rock cover or gravel will not be provided for the offshore pipe.

8.4.4 Precast Concrete Structures

The Discharge Structures at each outfall will be of precast reinforced concrete with precast reinforced concrete pile caps for pipe support. Pile caps will be 3 feet thick by 5 feet wide. The length of the pile caps will be approximately 14 feet for the offshore portion and approximately 31 feet for the inshore portion of the outfalls.

8.4.5 Piles

Open-end 24-inch diameter steel piling will be used for pipe support. The pile lengths will vary, up to a maximum estimated length of 45 feet.

8.4.6 Transition Structure

The Transition Structure will be of cast-in-place reinforced concrete constructed under dewatered conditions within a cofferdam. Access for maintenance will be through manholes in the top slab of the structure. Additional access to allow insertion and removal of stoplogs and removal of the flap gate will be through removable concrete panels in the top slab. Preliminary plans are to incorporate significant artwork with the transition project. The top slab and location of access opening will be designed to coordinate with the artwork.

8.4.7 Hydraulic Design

A friction factor (Manning's n) of 0.015 will be used for the concrete pipe, or a Hazen-Williams factor of C=80, to account for marine growth. The Elliott West Effluent Pipeline alignment has not been finalized. It is anticipated that there will be several bends in the alignment from the end of the Elliott West Effluent Pipeline to the beginning of the Outfall. It is assumed that all bends will be specially fabricated to the same standard as the main pipe barrel. Minor head loss coefficients used in the hydraulic model are listed below:

- 0.2 for 30 degree bends.
- 0.3 for 45 degree bends.
- 0.4 for 90 degree bends.
- 1.0 for outfall exit.

8.4.8 Cleaning

The Outfalls could be cleaned with 'pigs', mechanically or hydraulically propelled pipe cleaning devices, which could be easily used on the Denny Way Outfall Extension because it is not equipped with a tide valve. The Elliott West Outfall will have a duckbill tide valve, which would have to be removed before cleaning.

8.5 External Loadings

8.5.1 Earthquakes

The 1994 Uniform Building Code (UBC) (and 1994 Seattle UBC) defines the area as seismic Zone 3 with a seismic zone factor (Z) of 0.32.

8.5.2 Marine Vessels

The Outfalls are located in the Smith Cove East General Anchorage Area. The anchorage is used for vessels awaiting a berth at Cargill Grain Terminal. Vessels in the anchorage are typical deep-sea vessels, of the order of 550 to 740 feet in length. Their anchors weigh between 20 and 30 tons. According to a Cargill representative, Cargill's busy season is from November to March/April. During this period, the Grain Terminal averages one vessel on the berth, with an average of 1.5 vessels waiting in the anchorage. From May to October, the Grain Terminal typically has one vessel berthed but none anchored in Smith Cove East. At any time, there may be a period of up to two weeks with no vessels berthing at the Cargill Grain Terminal.

Lt. Percourt of Vessel Traffic Service indicated that six vessels have anchored in Smith Cove East from May through June and that the number is driven by commerce, which is difficult to predict. He estimated that 100 vessels per year use the Cargill Grain Terminal.

The risk to the Outfall from vessels anchoring in the area is low, mostly because of the shallow depth of water over the proposed Outfall and the infrequency of anchorage in this area. The vessels do not transit in water as shallow as 60 ft (the water depth of the proposed Outfall), as they would risk running aground. If a vessel did drop anchor in 60 feet of water, the stern would be too close to the beach. Captain Bill Bock of Puget Sound Pilots said that they direct vessels to drop anchor in about 300 feet of water, in a designated area located at the southwest corner of the anchorage. The southwest corner is the preferred anchor drop area because it is the farthest point from the Grain Terminal and gives the captain the most leeway.

The U.S. Coast Guard's comment letter of July 21, 1997, regarding the Draft Supplemental EIS states "It may be safely assumed that all vessels using the (Smith Cove General) Anchorage will drop anchor beyond the limit of the 500 foot extension."

8.5.3 Fishing Nets

There are treaty fishery events year around in the Myrtle Edwards Park area by the Muckleshoot and Suquamish tribes. Gill netting is the most common type of fishing, with boats longer than 20 feet using a power gill net reel. The gill nets are typically 1,200 feet long and 115 feet wide (200 meshes wide with a 7 inch opening). The nets are used with one end close to shore and the other end extending perpendicular to shore. The gill nets typically reach the bottom with the shoreward end set in less than 60 feet of water. Gill netting is most intensive from July to October, with five or more boats in the Myrtle Edwards Park area.

Little non-treaty fishing is done in this area. The Washington Department of Fish and Wildlife does not keep records of fishing volumes in the Myrtle Edwards Park area, but little sport fishing is done. In Elliott Bay, a fishery is open to sport fishers for rock fish and ling cod from May 1 to June 15. However, this fishery attracts few sports fishers. There is no non-treaty commercial trawling.

The risk of a gill net snagging on the diffuser or other exposed parts of the outfall is greater than the risk posed by anchors. The Outfalls will be designed to minimize the potential for snagging by fishing nets.

8.6 Other Design Parameters

8.6.1 Marine Operations During Construction

The Port of Seattle will continue operations throughout the construction period. The Cargill Grain Terminal, approximately 2,400 feet to the north of the proposed outfalls, is the only facility likely to impact upon the outfall construction operations. The terminal is used by about 100 ships throughout year, with November through March/April being the busiest season.

Local gill netters use the waters both along the line of the outfalls and to seaward. It will therefore be necessary to provide a well-marked exclusion area during construction and to mark the line and discharge point of the outfall upon completion.

8.6.2 Sediment Cap Materials

Any excavation within the sediment cap area will be replaced with clean granular material to original seabed level. Uncontaminated granular material excavated from the sediment cap area will be temporarily sidecast within the offshore construction area for later reuse. Any surplus material will be removed from the site.

Contaminated material, whether granular or not, will be removed from the site. It will not be stored, even temporarily, on the seabed.

8.6.3 CSO Discharges During Construction

The Denny Way Regulator is expected to continue to function during construction and any resulting flows will be discharged through the existing outfall. Because the Elliott West Outfall alignment will pass through the existing alignment of the Denny Way Outfall, the Denny Way CSO Outfall structures must be demolished prior to constructing the Elliott West CSO Outfall. For construction purposes, the discharge flows given in Table 8-5 will need to be considered.

Table 8-5
Discharge Flows During Construction

Month	Monthly Discharge Volume (MG)
June	20
July	20
Aug	25
Sept	30
Oct	35
Nov	40
Dec	45
Jan	50
Feb	50
March	50
April	50

May	20